ETI ELECTRONICS TODAY INTERNATIONAL

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SATELLITES FROM SURREY

12 Months, £5M, 25 Careful Designers - Pioneering Low-Cost Satellites

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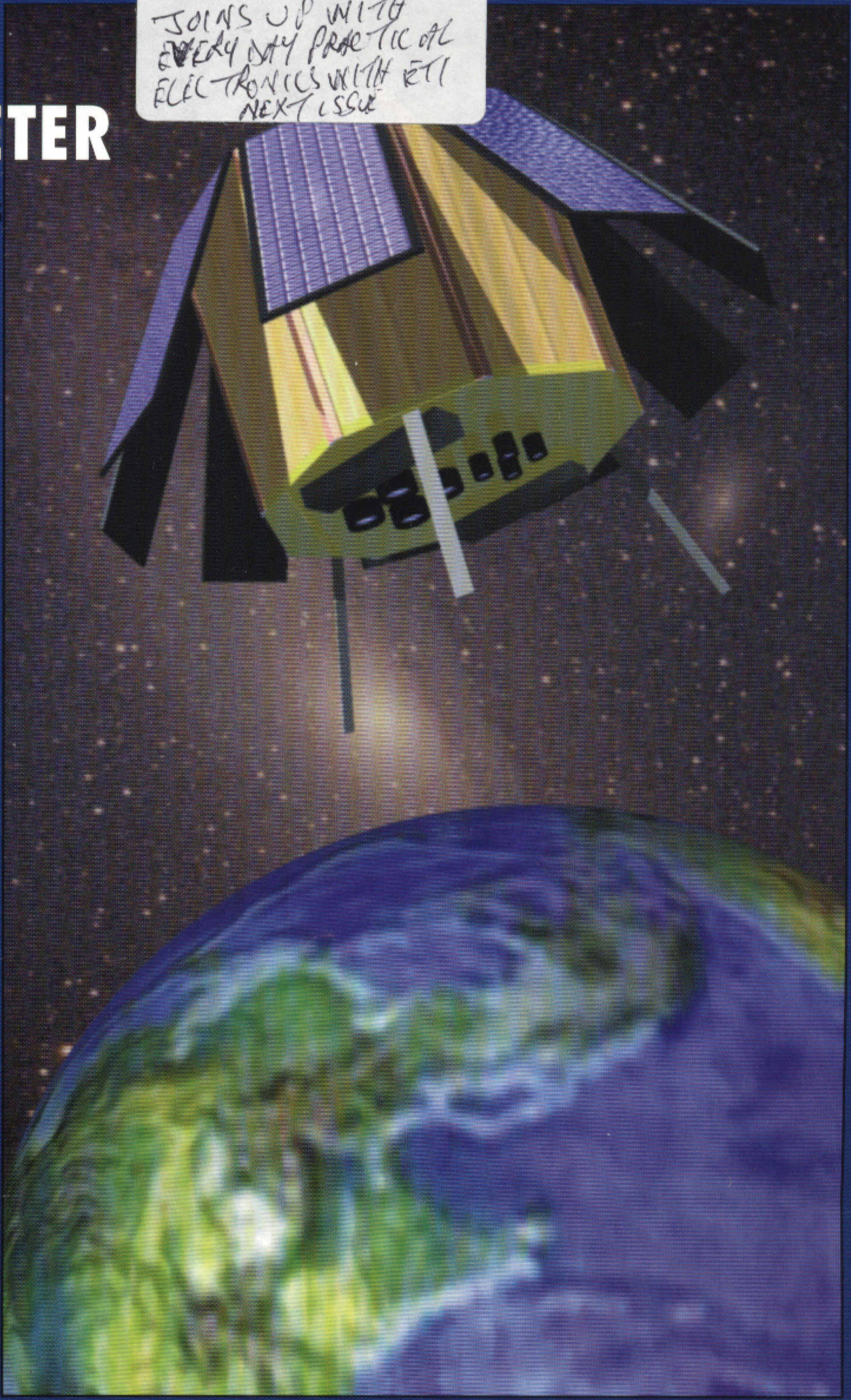

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1st January - 28th January 1999

Electronics and Computing • Projects for the Future

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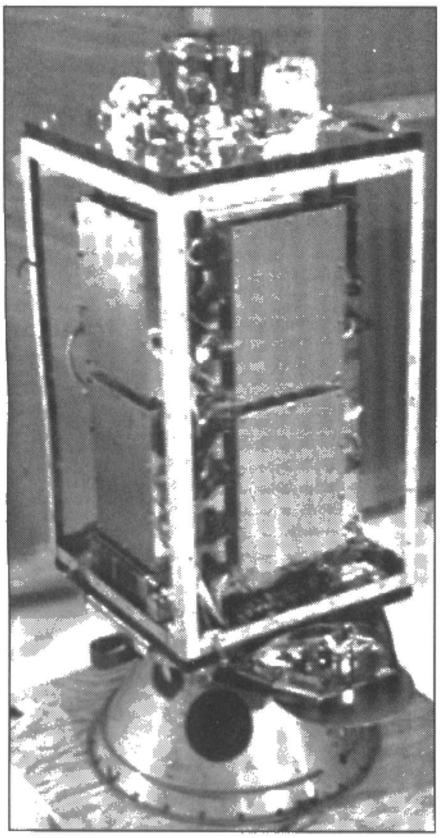
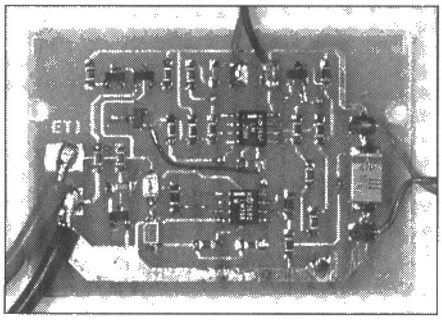
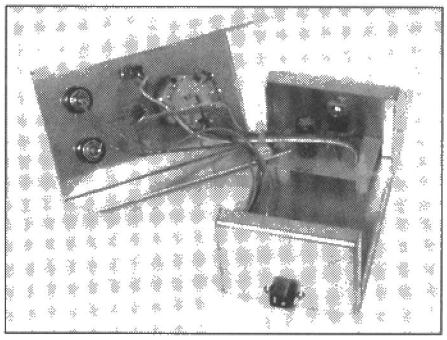
& Features Projects







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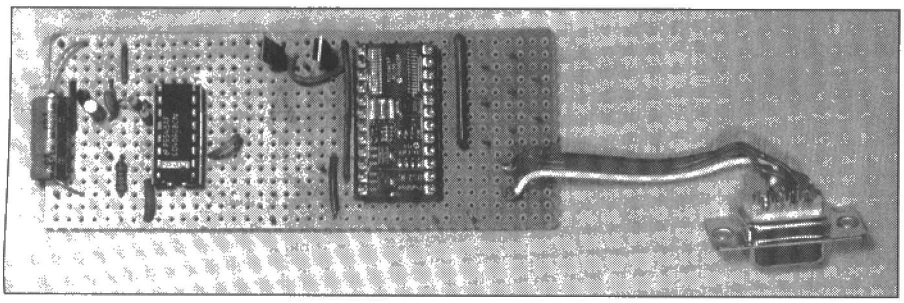


Clockwork Radio Gives New Meaning to 'Spring Green'

The "Clockwork Radio", as the BayGen Freeplay radio is familiarly known, first came to light in 1994. Inventor Trevor Bayliss designed the prototype for use in remote areas of the Third World, where batteries are often hard to obtain, and frequently prohibitively expensive for local people. Broadcast radio can link scattered communities with regional news and education, as well as entertainment. After the advent of the clockwork radio, poor communities did not have to be deprived of this highly-valued service because they had no mains power source and were unable to afford batteries.

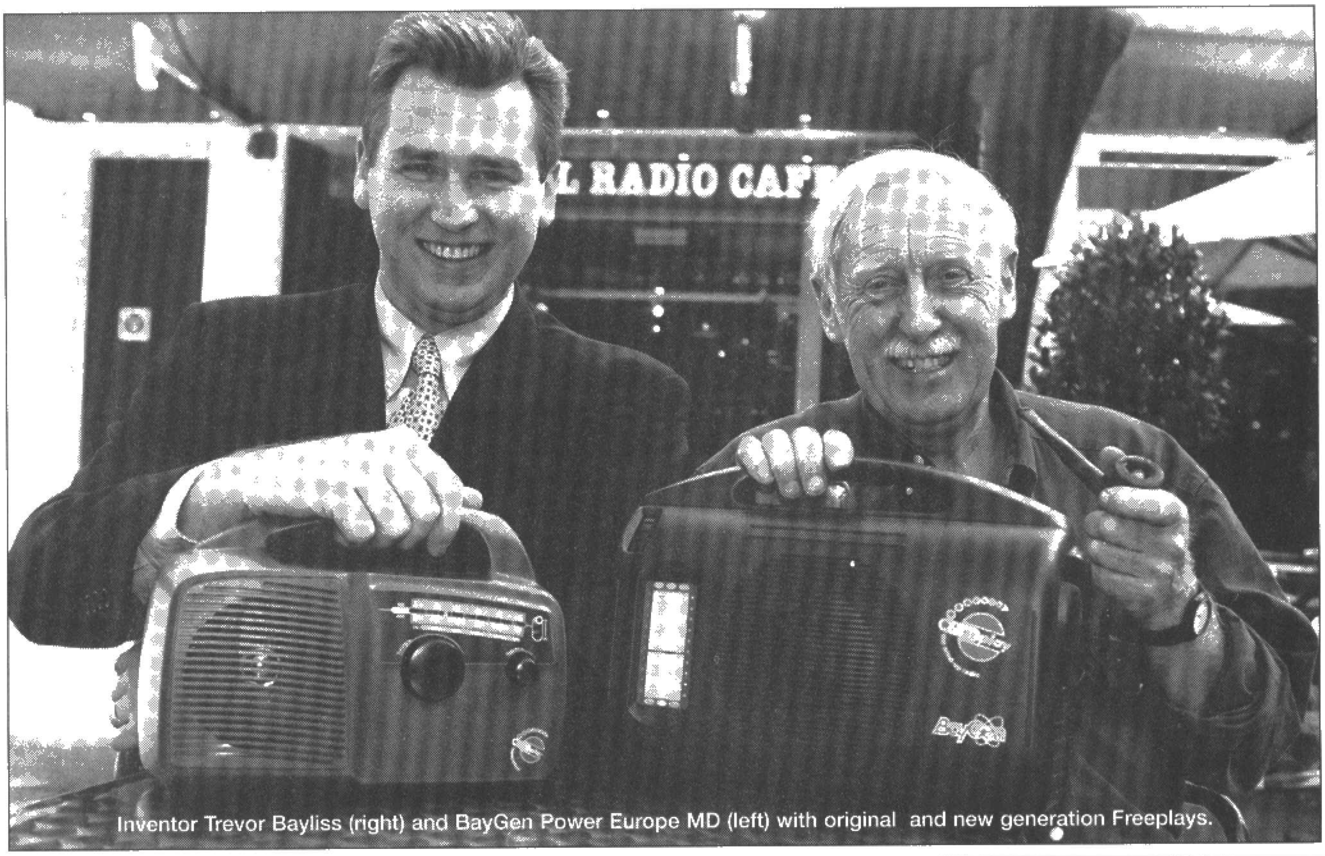
In 1997, BayGen launched the "new generation" of the Freeplay. The new radios are smaller and lighter than the original Freeplays, which were ruggedised to withstand air-drops into regions where a light aircraft might not be able to land safely. As many of our readers will have noticed, in 1998 the Freeplay began a new career as an environmentally-friendly style accessory. Concern about the polluting effects of discarding used batteries has been mounting, and the clockwork radio is the example par excellence of essential electronic services without a costly consumable power source.

The Freeplay operates from a carbon steel spring which is from one spool to another. The input winding is via an external fold-in handle. 20 seconds of winding will give an hour's radio play at low volumes. The motor transmission consists of a three-stage gearbox which increases the input rotation by 1:1,000. The transmission output drives a DC generator which produces up to 100mW of power. An optional DC adaptor is available for the times when your arms are more tired than your wallet. The dimensions are 200 x 200 x 290 mm and weight is 2.4kg.

For Christmas, BayGen have released a limited edition of 1600 in see-through holly-green casework, which has the added charm of displaying the shapely gear-wheels in their stately circular progress while you listen. A little too chunky to make a good handbag, if your Freeplay ever finally runs out of Wind, with a bit of ingenuity you could consign the works to a pride of place on the mantelpiece and convert the case into a handy toolbox.

BayGen has already produces a wind-up torch. With increasing investment in the company in mid-1998 by General Electric Pension Trust, part of the US multinational General Electric, we can expect BayGen to continue research and development into further electrical equipment powered by "human energy technology".

New generation Freeplay radios are available from major high street electrical and department stores for around £59.95. For further information, contact BayGen Power Europe Ltd., Claverton House, Longwood Court, Love Lane, Cirencester, Glos. GL7 1YG. Tel 01285 659559 Fax 01285 659550 Email baygen@lineone.net



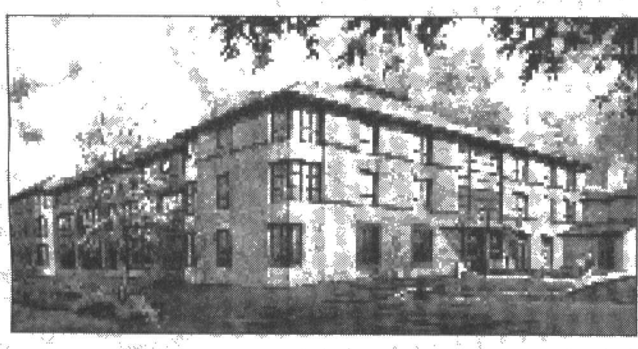
Inventor Trevor Bayliss (right) and BayGen Power Europe MD (left) with original and new generation Freeplays.

Surrey and Tsinghua Chinese/British Commercial Satellite Project

SURREY SPACE CENTRE

A University of Surrey company, Surrey Satellite Technology Ltd. and Tsinghua University in China have formed a collaborative joint venture company in Beijing to develop advanced microsatellites for China. A market for over 100 small satellites over the next 5 to 8 years has been identified within China, and SSTL is the first foreign company to establish a joint venture in this market. They are likely to access business worth some £300 million.

The 25-year joint venture company, to be known as the Tsinghua-Surry Small Satellite Company (T-SSSC), is the result of more than five years of extensive work SSTL in China, promoting the use and applications of sophisticated small satellites as a rapid and lower-cost approach to meeting China's space requirements. This is the first private satellite manufacturing company to be formed in China, reflecting the interest of the Chinese government in introducing further commercial market forces into the Chinese space industry.



The exchange of contracts for the new joint company in Beijing in October 1998 was witnessed by British Prime Minister Tony Blair, who wished the partners success.

The first £3million contact for T-SSSC has already been signed between Surrey and Tsinghua for a 50kg microsatellite (to be called Tsinghua-1) which will be the first demonstrator for a group of seven microsatellites to provide daily world-wide high resultion imaging for disaster monitoring and mitigation, planned for launch in 2000. The microsatellite will also carry out communications research in Low Earth Orbit at the end of 1999 after launch on a Chinese Long March rocket.

Last September (1998) the Surrey Space Centre and the Tsinghua Aerosapce Centre launched a joint Tsinghua Surrey Small Satellite Research Centre which will specialise in advanced academic research and development of microsatellite and nanosatellite technologies.

For more information contact Dr. Wei Sun, Marketing Manager, Surrey Satellite Technology Ltd., Surrey Space Centre, Univeristy of Surrey, Guildford, Surry GU2 5XH. Tel 01483 259878 Fax 01483 259503 Email s.wei@ee.surrey.ac.uk

EMC Website Has Standards Updates and Product Information

EMC (electromagnetic compatibility) expert company Schaffner has redesigned and upgraded its website making EMC expertise available to engineers and engineering decision makers all over the world. The site at www.schaffner.com gives up to date listings of the latest EMC standards, links to standard-setting bodies around the world, news and comment on EMC issues, together with product information and a fast response service that puts callers in touch directly with local EMC experts.

Engineers must now consider EMC compliance and EMI (electromagnetic interference) suppression as fundamental requirements in the design of all electrical and electronics products. World legal requirements are complex and constantly changing, varying from one market to another. As participant in many EMC standard-setting committees, Schaffner can provide some of the most up to date standards on the web.

The website offers a quick reference guide to standards as well as revision and update news and a comprehensve glossary of EMC terms. Each IEC standard appears with a short description, and a list correlates European norms including prENs and prENVs with international IC and CSIPR standards. Engineers seeking more detailed information on these international standards, or on national standards activities, can use the site list of links to committees and quality organisations worldwide.

The site also offers extensive EMC-related product and service information. An Info Fastrack service provides product-specific forms with a selection menu which is routed directly to the local Schaffner office, minimising delays.

For more information contact Michael Lowe, Schaffner UK Ltd., Ashville Way, Molly Millar's Lane, Wokingham, RG41 2PL. Tel. 0118 9770070.

STOP PRESS ANNOUNCEMENT

ETI
ELECTRONICS
TODAY INTERNATIONAL

Next Month . . .

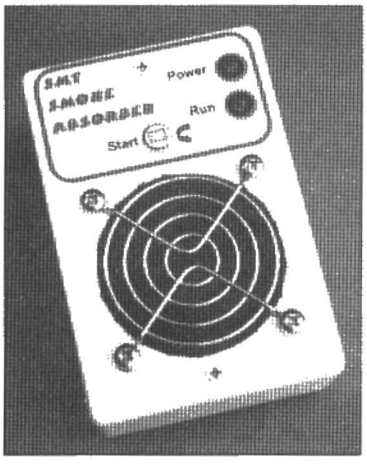
ETI JOINS FORCES WITH EVERYDAY PRACTICAL ELECTRONICS

EVERYDAY PRACTICAL ELECTRONICS

Next month ETI will join forces with Everyday Practical Electronics (EPE) to bring you the best possible electronics magazine, with the widest range of projects, features and news. All the information you are used to getting in ETI plus more from EPE.

We have just negotiated a merger of the two magazines and we are sure you will benefit with more projects, more theory, more help and more products to buy in every issue.

Watch out for the combined ETI and Everyday Practical Electronics logos on the news-stand on February 5. The issue will feature the projects shown here . . . and much more.



SMT Smoke Absorber

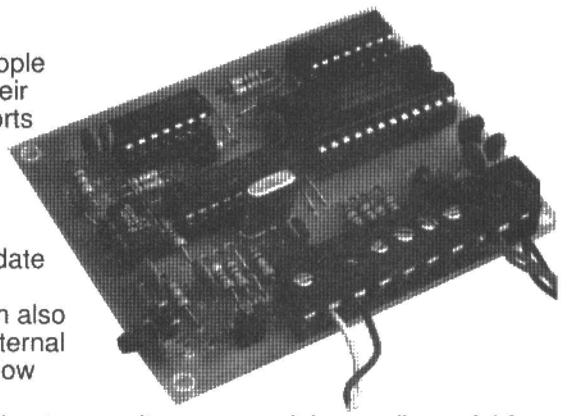
When working with tiny surface mount devices (SMDs) the constructor is drawn closer to the circuit in order to get a clear view of the soldering operation. Close working with SMDs therefore involves a much higher risk of solder fumes being inhaled and potential bronchial problems. The smoke absorber is very compact and can be placed close to any circuit during population. It will remove the solder fumes from the immediate area and a built-in charcoal filter will provide a degree of filtration and absorption.

The smoke absorber is triggered by the heat from the soldering iron and it switches off after about half a minute unless re-triggered. Automatic control is very convenient, as the soldering process tends to be intermittent and remembering to switch the unit on and off is quite a distraction.

March Issue On Sale Friday February 5 . . .

Next Month . . . Next Month . . .

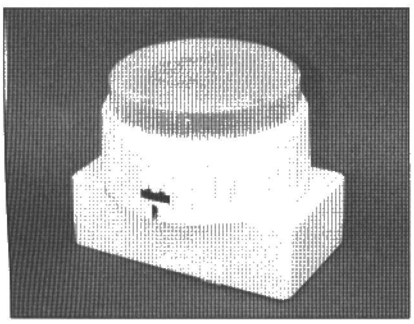
Time and Date Generator



With the availability of cheap video cameras, more and more people are adding surveillance cameras to the exterior and interior of their homes. Cameras connected to a video recorder will record all sorts of amusing and sometimes nefarious activities, and usually it is useful to know the precise time that these events occurred.

This project was designed to add time and date information to a multi-camera video security system designed for home use. The generator inserts a steady and easily readable time and/or date caption onto any composite video signal. The time and date information is displayed at the bottom of the screen. The unit can also optionally display a camera number (1 to 8) provided from an external camera selector by inputting a 3-bit camera address. This will allow the user to know which one of eight cameras is currently active.

Although originally intended for adding time and date information to security cameras, it is equally useful for adding time and date to home videos for those who have not got this capability built into their video camera. This design is based on a PIC16C84 which performs the real time clock function and display character generation. The main features of the unit are: ● Adds time or date or both to a composite video signal (NTSC, PAL and SECAM video signals) ● Selectable character height of 5, 10, 15 or 20 lines ● Inverse or normal video display ● Day and month display are swappable for those who prefer the American standard ● Leap year correction ● Year 2000 compliant.



Auto Cupboard Light

Commercial battery-operated cupboard lights are widely available in DIY stores and by mail order from electronic component suppliers. These lamps are useful as a simple means of lighting up a cupboard or other dark area.

They are also handy for garden sheds and other places where no mains supply exists. The fact that they are battery operated makes them particularly attractive for children's bedrooms because, unlike conventional mains lights, they are completely safe. The one drawback is that if they are left on, the batteries are exhausted with monotonous (and expensive) regularity. This simple project provides automatic timed control of the light.

Plus ● New Technology Update ● Circuit Surgery ● Practically Speaking ● News

March Issue On Sale Friday February 5 . . .

ETI ELECTRONICS TODAY INTERNATIONAL News...

DTI Has Another Crack at Encouraging Girls Into Science and Technology

Peter Mandelson, Secretary of State for Trade and Industry, has launched what the DTI calls "an innovative poster campaign" called "Go For It" to encourage more girls to consider being pilots, lighting technicians and civil engineers. The campaign, developed by the DTI's Office of Science and Technology, features six posters of young, female role models working in science, engineering and technology jobs. This follows research that among 14-16 year old girls that shows that many are alienated from technology by what they see as the impersonal and value-free content of science. Few have met a female engineer, and the most important factors affecting their career decisions and personal and social.

Mr. Mandelson said: "To many young people, and young women in particular, are simply unaware of the sort of opportunities that science and technology qualifications can lead to. As a result, employers, especially in engineering and IT, are having difficulty in recruiting the skills they need, and in attracting young women entrants.

"There is no reason why women should not become leaders in this technological age. It's time we had a "can-do" attitude that will enable us to grasp at opportunities and push Britain to the forefront of the global knowledge-driven economy.

"This campaign targets girls of all abilities and shows them that a career in science, engineering or technology offers more than the stereotypical image of science labs and hard hats.

"We are sending these posters out to every science teacher in every mixed and girls' secondary school in the country to push the message that science, engineering and technology is fun and is for everyone."

The posters seek to address the fact that 85 per cent of the full time science, engineering and technology workforce are male. They also aim to correct the misconception that these careers always require exceptional intelligence and are largely based indoors in laboratories or workshops.

The six role models in the campaign are Sandie King, Senior Chemical Analyist; Jo da Silva, Civil Engineer; Kerry Lomas, Airline Pilot; Clare O'Donogue, Senior Theatre Lighting Technician; Belinda Drew, Electrical and Mechanical Technician and Farzana Patel, Assistant Forensic Scientist. They explain how their chosen careers have expanded their horizons professionally and socially, and how science, engineering and technology can be fun.

Editorial: Round the Corner, page 76.

New Palstar Model From Nevada

Nevada has added a new model to catalogue of Palstar regulated power supplies. The PS50 supply delivers 40 amps continuous output (50A peak) with high stability. It has a thermostatically controlled cooling fan system, short circuit and overload protection and precision front panel meters. The unit measures up at 205mm (W) x 157 mm (H) x 335 mm (D), weighs 19 kg approx and costs £144.63 plus VAT. Palstar precision low voltage power supplies are suitable for Amateur transceivers and receivers and bench supply, auto and marine radio and other uses.

For more information contact Nevada, 189 London Road, North End, Portsmouth, Hants PO2 9AE. Tel 01705 662145 Fax 01705 690626 email info@palstar.com

Sightmagic Takes Over EASY-PC and Number One Systems

Gloucester-based software development company Sightmagic has acquired Number One Systems, owners and published of the popular Easy-PC family of CAD software, plus a range of powerful simulation products.

Sightmagic has some 120 man-years' experience in PCB CAD development. The range of products will continue to be developed, marketed and supported by Sightmagic: Easy-PC For Windows, Analyser III, Layan, Z-Match, Pulsar and Filtech.

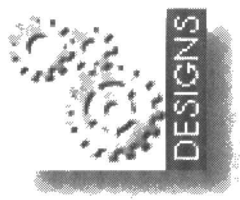
Bob Williams, Sightmagic's marketing manager, said: "The acquisition of the Number One Systems name and their software tools presents an exciting opportunity to bring our team's many years of experience in PCB CAD development into the further enhancement of the Easy-PC range of products. We intend to make Easy-PC for Windows by far the best value sub-£500 PCB layout product on the market today." Sightmagic have already completed the next release of Easy-PC For Windows, with eight new features, which is now in test for release in February, and have plans for at least 10 more features in the following release during the summer. The other simulation products are also due to receive consxiderable enhancements in 1999.

For more information contact Sightmagic, Oak Lane, Bredon, Tewkesbury, Glos GL20 7LR. Tel. 01684 773662 Fax 01684 773664 Email sales@sightmagic.co.uk .

Readers wishing to follow up the offer in issue 12 1998 of ETI should contact Sightmagic with their copy of Issue 12.

ETI ELECTRONICS TODAY INTERNATIONAL News...

Patent Office Reduces Patent Charges and Posts Internet Application Form



The Patent Office in the UK has abolished the patent application fee, the first patent office in the world to do so.

This, and some other measures, are part of a Government move to encourage businesses and inventors to protect their intellectual property rights by asserting their copyright and filing for patents, designs and trademarks. Overall Patent Office charges have been cut by 20 percent, and the standard patent application form has been posted on the Internet for faster access to computer users.

Visiting the Patent Office in Newport, South Wales, Dr. Kim Howells, Minister for Compeition and Consumer Affairs, said: "By the end of the year, the UK Patent, Designs and Trade Marks Registers will all be freely available on the Patent Office web site, as will all the European and Patent Co-Operation Treaty patent applications published in the last two years."

Non-web users can contact the Patent Office as usual at Cardiff Road, Newport, South Wales NP9 1RH. Tel 01633 814000. The Patent Office website is at www.patent.gov.uk and contains a wealth of information on copyrights and patents. Mysteriously, the website address was not included on the notification circulated to the press, but we located it in the normal way using an Internet search engine. If in doubt about the location of the information you require, call the switchboard and ask for assistance.

New Charger Technology Adapts to Battery State

A new company, ACT Europe, is introducing a new battery charging technology known as Dynamic Electrochemical Waveform. The technology has been designed to overcome "virtually all the limitations of rechargeable batteries", according to ACT, increasing their charge capacity, tripling battery life, eliminating memory effect and significantly reducing charge time. Developed in the USA by Advanced Charger Technology, Inc., the patented technology is put to use in the company's range of ACTivator battery chargers for mobile radios and cellular phones.

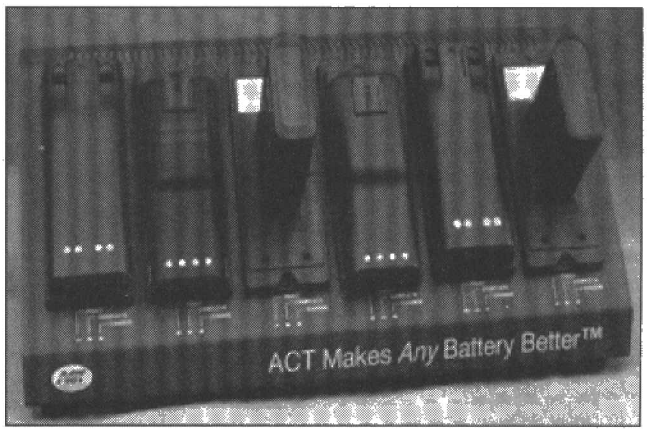
Advanced Charger Technology's DEW system is implemented by an intelligent microprocessor which analyses the battery's state of charge several times a second and instructs the charger to use an intelligent algorithm to achieve optimum charge. The DEW family of technologies works on lithium ion (Li ion), nickel metal hydride (NiMH), nickel cadmium (NiCd) and lead acid batteries, and is available only in the ACT 'ACTivator' line of battery chargers or in various licenced products.

The ACTivator is the only charger capable of monitoring the internal condition of a battery and changing the waveform of the charging current accordingly. It is also the fastest battery charger now currently available, able to charge a two-way radio NiCd to 100 percent charge in 30 minutes, a Li ion cellphone battery to 100 percent in 60 - 90 minutes and a lead acid electric vehicle battery to 80 percent capacity in 20 minutes.

ACT manufactures ACTivator two-way radio battery charger/conditioners and licenses DEW technology. The photograph shows the Maintainor, a state-of-the-art emergency maintenance charger designed for users who need additional supplies of batteries ready for service at a moment's notice. The Maintainor has a patented "maintenance mode" that will fully discharge and recharge batteries left on the charger every two weeks

ACT Inc. in the USA offer a 30-day trial of the TBC-25 ReACTivator or TBC-21M Multi-Chemistry ACTivator for use on two-way radio batteries to "test drive" in the user's working environment.

For more information contact Advance Charger Technolgoy (Euorpe) Ltd., Unit 2, Union Quay, Cork, Ireland. Tel. +353 21 311373 Fax +353 21 311189 or Advanced Charger Technology Inc.'s website at www.actcharge.com.



The TBC-65 Maintainor with six interchangeable adapters

OVERSEAS READERS

To call UK telephone numbers, replace the initial 0 with your local overseas access code plus the digits 44.

ETI ELECTRONICS TODAY INTERNATIONAL News...

New 40,000-Item Component Catalogue On CD-Rom

Established German component distributors Schuricht Elektronik have launched their 40,000-item component catalogue on CD-rom in the UK. The rom catalogue is available through their UK agents, Cyclops Electronics of York.

The catalogue carries components from 250 manufacturers. Shuricht also runs a service called KatalogPlus! which undertakes to obtain standard parts from manufacturers in the catalogue to order, even if the specific part is not in the current catalogue.

Shuricht's standard delivery charges in the UK are currently £6.60 for delivery within 48 hours and £18 for next day delivery up to 3 kg. Single items can be ordered without extra charge. The company began developing its CD-rom catalogue 1996, including the whole Seimens range, and has won an industry award for design, information content and easy operation in 1997.

Users can create and save their own order numbers for components if desired, and will find the same component under their own number on subsequent orders.

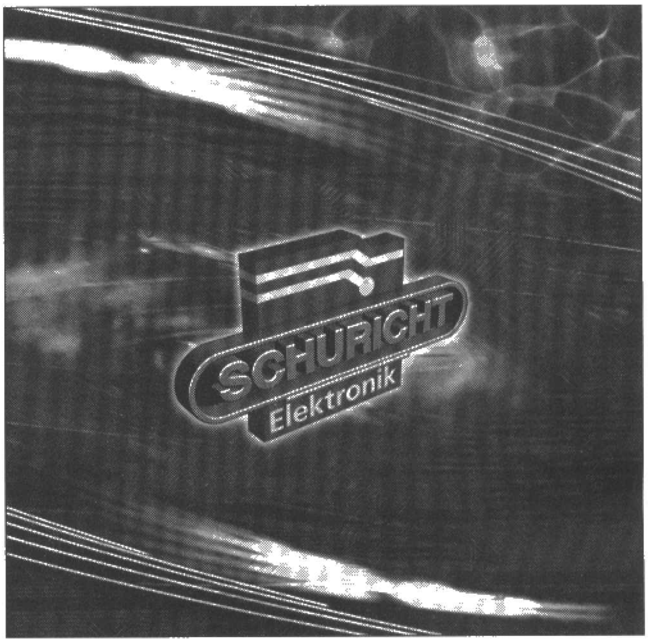
Availability can be checked and orders can be placed via the company's website at www.shuricht.co.uk, and the CD-rom catalogue can also be updated directly from information on the website. Both the CD-rom and the the server store around 14,000 datasheets.

Michael Sinclair, Sales Manager of Cyclops Electronics says, "The whole service is geared to low volume applications; research, development, repair, maintenance, education, test and small production runs." "One-piece deliveries" are no problem.

The CD-rom is free from Cyclops Electronics and will be sent out on the day of order.

For more information contact Cyclops Electronics, Link Business Park, Osbaldwick, York YO10 3JB. Tel 01904 436444 Fax 01904 436544 Email info@schuricht.co.uk

ETI would be interested to hear in due course what readers using the Shuricht catalogue think of the service and product range.



MODMODMODMODMODMOD

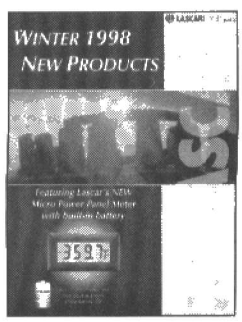
In the first part of the PC-Controllable 4-Line Dot Matrix Display (ETI Volume 27 issue 10 11th September 1998) an error has turned up in the Parts List on page 40: the headers PL7 an PL8 have the wrong part number. The correct number is Farnell 511-821. In Part 2, page 39, under Panel 1, Panel 2, Panel 4 *P4 tile select, the wrong links are listed for Panels 2 and 3. Panel 2 links are 3-4, 5-6, 7-8. Panel 3 links are 1-2, 5-6, 7-8.

Author Robert Coward's email address has now changed to ROBERT_COWARD@3COM.COM

Meter Specialists New Winter Product Guide

Metering specialists Lascar Electronics' new 1998 winter New Product Guide, Lascar Link, is now available free of charge. Containing information on a wide variety of new products, including the company's new ultra-low power panel meter, the DPM 720, the winter guide provides design and application engineers with a preview of some of the modules scheduled for introduction in Lascar's 1999 short-form catalogue due for release in January.

For more information or a copy of the New Product Guide contact Lascar Electronics at Module House, Witeparish, Salisbury, Wilts SP5 2SJ, UK. Tel. 01794 884567 Fax 01794 884616 Email lascar@netcomuk.co.uk



Small Satellites From Surrey

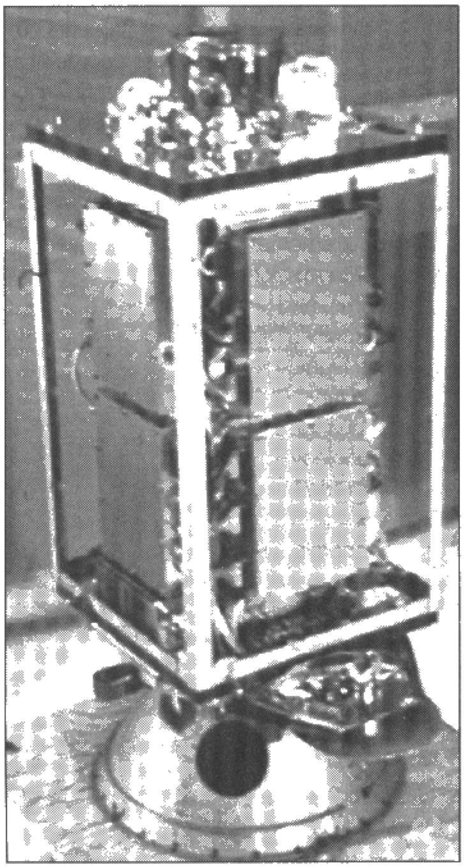
Surrey University created the UoSAT programme and gave birth to a business which has carried small, low cost, space-industry "affordable" communications and research satellites all over the world.

Earlier this winter, the University of Surrey's own satellite technology business SSTL (Surrey Satellite Technology Ltd.) announced the formation of a Collaborative Joint Venture (CJV) Company with Tsinghua University is Beijing, China, to develop new microsatellites for the Chinese market. (See News in this issue.) The joint venture is the first private satellite manufacturing company in China, something of a milestone for the space industry in one of the world's largest countries, as well as for the UK company. However, Surrey Satellite are used to being pioneers, having been formed as a business enterprise by the University back in 1969. These days it is not uncommon for an educational and research establishment to form a company (or companies) to take its work to market, but in those days it was rare. Surrey however are pioneers in the technology of satellites as well as the marketing, and it is this specialisation that made it more than appropriate for them to maintain control over their own research.

Previously, SSTL was chosen as the only company outside the USA to be an approved supplier to NASA.

The first satellite planned is a 50-kg microsatellite to be known as Tsinghua-1, which will carry out communications research in low Earth orbit (known as LEO) from the end of 1999. The contract is worth about £3million and the Government clearly hopes that it will open the door to bigger things, since they sent Tony Blair to see the happy venturers on their way. The joint venture is set to run for 25 years, during which there will no doubt be developments that have not been dreamed of yet.

Loosely defined as falling between 10 and 100 kg in weight and £2-4million sterling in cost, the class of satellites known as microsatellites have in recent years proved to be the most effective small satellite in terms of both versatility and cost for civil and military applications, "very effectively, rapidly, and at low cost and risk".



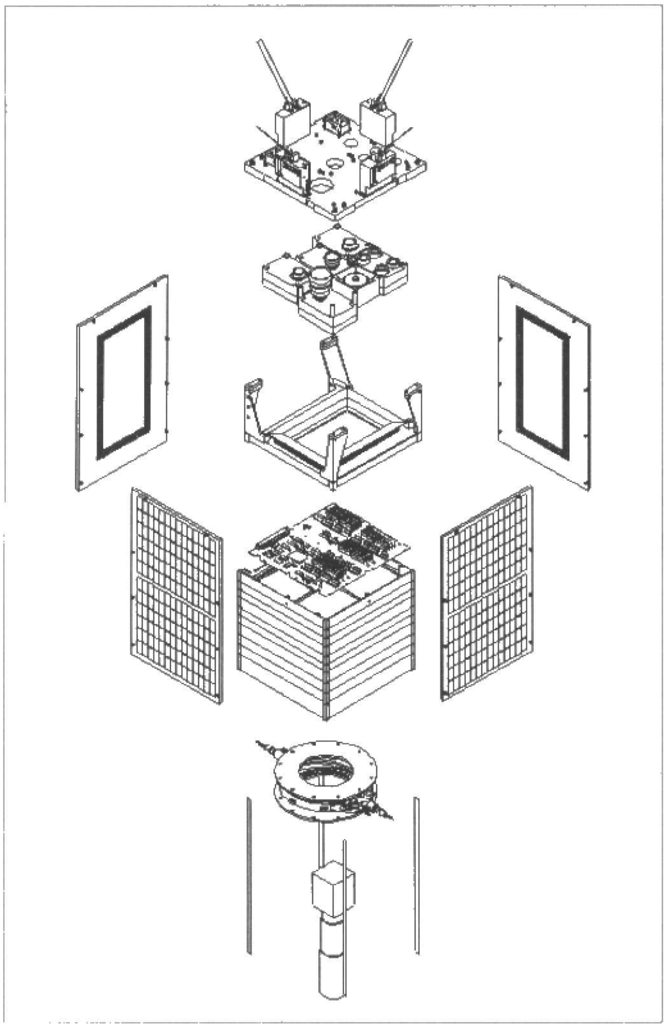
It began here: UoSAT-1, Surrey University's first microsatellite, was launched in 1981

The University of Surrey embarked on its first satellite programme in 1978. This gave rise to the UoSATs, with the launch of UoSAT-1 carrying a University of Surrey research payload in 1984. Gradually, but particularly since the UoSAT programme began to carry payloads for customers other than the University in the early 1990s, Surrey has built up an international reputation as a pioneer in the field of small, low-cost satellites for commercial applications as well as research missions. It continues its research and development under the small satellite battle cry: "smaller, faster, cheaper and better".

The first two UoSATs were based on a conventional satellite framework onto which the modules containing the satellite's electronics and payloads were mounted. The wiring harness arrangement that connected all the systems together is described with understatement as "complex". The need to fit a number of different payloads into a standard launcher envelope with a 50kg weight ceiling, along with many other demands imposed by developments in the electronics industries (including electromagnetic compatibility (EMC)) gave rise to the development of a new satellite framework design at Surrey in 1986. The SSTL modular microsatellite design has no separate skeleton, but works by stacking a series of custom module boxes each machined to the same dimensions. This block of modules itself forms the "body" of the satellite, to which the external solar panels and other instruments are bolted.

The main module boxes contain the satellite subsystems, such as batteries, power conditioning, on-board data handling systems, comms and attitude control. The payloads are housed either internally in similar stacked boxes, or on externally top of the stack near the antenna and attitude sensors, as appropriate.

The stacked modular design - you could think of it as having a "virtual" skeleton comprising the dimensions



An exploded view, showing the modular construction of SSTL microsatellites. The solar panels are bolted to the sides of the central stack of modyules

and the bolts - not only allows flexibility, but contributes to the speed of design allowing the satellite to progress from "order-to-orbit" typically in 10 - 12 months. The system has been used successfully on seventeen missions to date, each with a variety of different types of payload and mission requirements.

The electronics sent into orbit on these microsatellite missions are a combination of space-proven satellite subsystems, and sophisticated but not necessarily space-proven electronics. This approach, described as "layered architecture", allows high performance in various fields, and achieves the necessary degree of operational redundancy to ensure a good change of mission success by using a variety of alternative technology approaches rather than by duplication of a single, well-tried approach. The comparative speed and cheapness of microsatellite makes this degree of trial-and-error economic, and the ability to employ technology that has not been previously space-tested contributes to the speed and responsiveness of the small-satellite design. Small satellite launches can afford a moderate degree of experimental risk to take new technology into space faster, that would be inappropriate for a large satellite costing in excess of £100 million and several years' development to get into orbit.

The earliest UoSAT missions were able to hitch a ride virtually free on USA and USSR launches. The need for reasonably regular and predictable but comparatively low-cost launches was met in the 1980s by the Ariane Structure for Auxiliary Payloads (ASAP), specifically to provide economic launches for 50kg microsatellites into LEO and GTO positions on a commercial basis. One advantage of the commercial approach is that it puts ventures on an independent footing that relies on the needs of the space research market, rather than on the political will to Government funding: having less of the appearance of pure science, perhaps, but perforce a more responsive relationship with actual demand for telecommunications and other research.

ASAP now cannot meet the demand for small satellite launches by itself, and other launch programmes are coming into use. By a twist of fate, old stockpiles of intercontinental ballistic missiles (ICBMs) are now being used as small launchers under the militarisation programme.

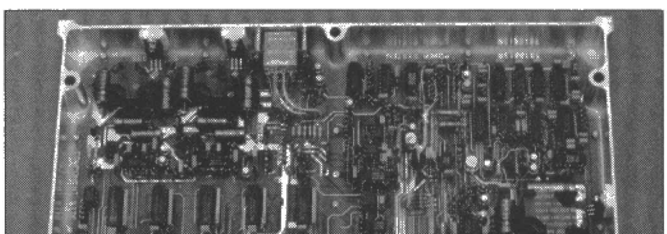
Advanced platforms

Microsatellite platforms are being improved in performance and payload capability as research and experience continues to develop. SSTL's latest versions can provide the following specification:

- distributed telemetry/telecommand for easy expansion
- 5 Mips (386 processor) on-board computer and 256 MB ramdisk
- 1 Mbps on-board lan (local area network)
- autonomous GPS navigation (+/- 50 metres)
- attitude determination to 0.001 degrees of nadir
- 0.25 degrees rms nadir-pointing pitch/roll axes, 2 degrees yaw axis
- 128 kbps BPSK downlinks

Without accurate attitude control, the satellite can neither process sunlight through its solar panels correctly (leading to loss of power and ultimately complete loss of control) nor maintain its communications links with Earth accurately (leading to loss of contact and ultimately possible loss of research data). Small satellites are vulnerable to instability, so the importance of a finer degree of attitude control can be appreciated.

Communications and Earth observation equipment among the payloads require an Earth-pointing platform. Satellites sent up for Earth observation purposes will become effectively useless if this function is lost due to instability. Generally, in the family of SSTL microsatellites, the attitude has been maintained



A typical single satellite module built into a chassis of standard dimensions:

to within 0.3 degrees of nadir by a combination of gravity-gradient stabilisation (see box below) using a 6-metre boom and closed-loop active damping using electromagnets under the control of the onboard computer.

Attitude determination is provided by Sun and geomagnetic field sensors, and star-field cameras, and the orbital position determined as now to within +/- 50m by the on-board global positioning system (GPS) receiver. The power is generated from four gallium arsenide solar panels which mounted on the sides of the body-block, giving about 35W each and feeding a 7amp-hour NiCd battery.

VHF uplinks and UHF downlinks using fully error-protected AX.25 packet-link protocol at 9.6 to 76.8 kbps provide the communications. Several hundred kB of data can be transferred to small ("brief-case sized") communications terminals.

As with most electronics systems at the end of the 90s, the software is the crucial element of the satellite's capability. The data handling is based around an 80C386 onboard computer running a 500kB real-time multitasking operating system with a solid state 128 MB CMOS ramdisk.

There is a secondary 80C186 computer with 16 MB of static ram, two 20-MHz T805 Transputers with 4 MB of sram and about a dozen other microcontrollers. The satellite normally operates on the main onboard computer and real-time operating system.

In line with the need for the software to be as advanced as possible for the job in hand, all the software on board the satellite is loaded remotely once the satellite is in orbit, and can subsequently be upgraded as needed from the controlling groundstation. The telecommand instructions required are compiled on the ground as a "diary" and transferred to the satellite for execution then or (more normally) subsequently.

Measurement data for remote transfer, or telemetry, gathered by the payload systems or taken from the satellite's functions are collected in the 386 and stored in the ramdisk until the satellite is within range of the control station.

Input from the attitude sensors is fed to control algorithms stored in the onboard computers and used to operate the satellite's attitude control systems. This complex of sensors and fully-upgradeable software allows automatic and autonomous control of the satellite and its payload systems, and does not require constant monitoring.

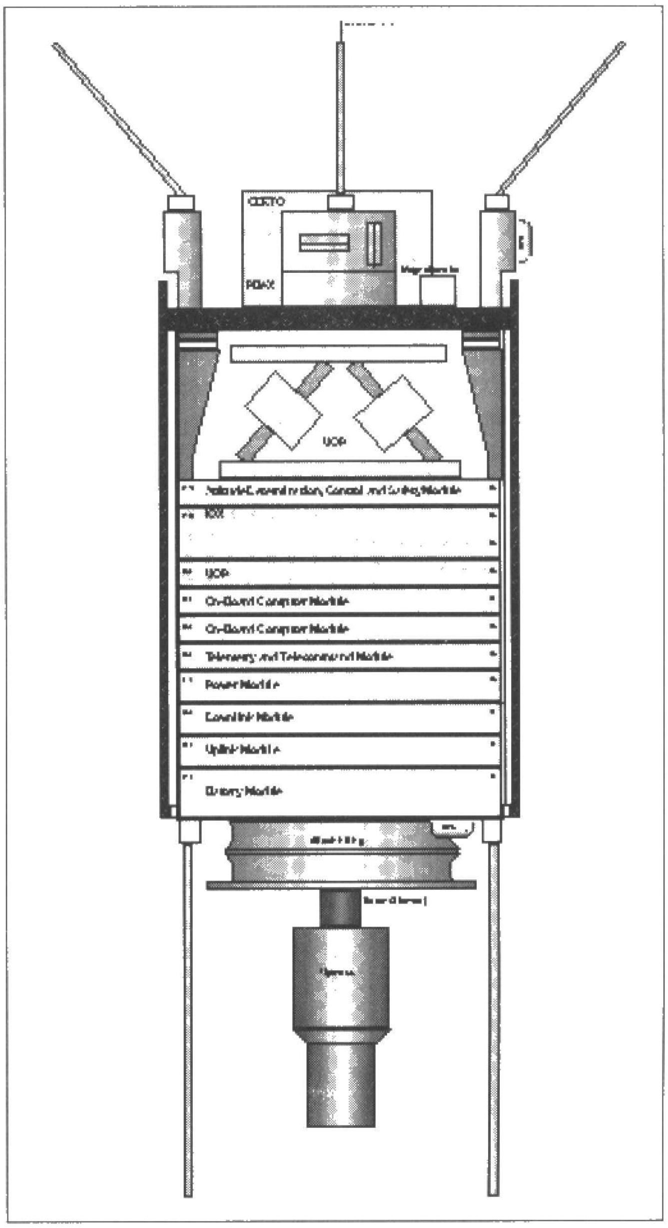
SSTL's most advanced microsatellites are represented first by FASat-A (for Chile), launched in 1995, FASatBravo (also for Chile, 1997), TMSAT (Thailand, 1998), TiungSat-1 (Malaysia, projected for 1998) and PICOSat (US Airforce, projected for 1999).

International interest

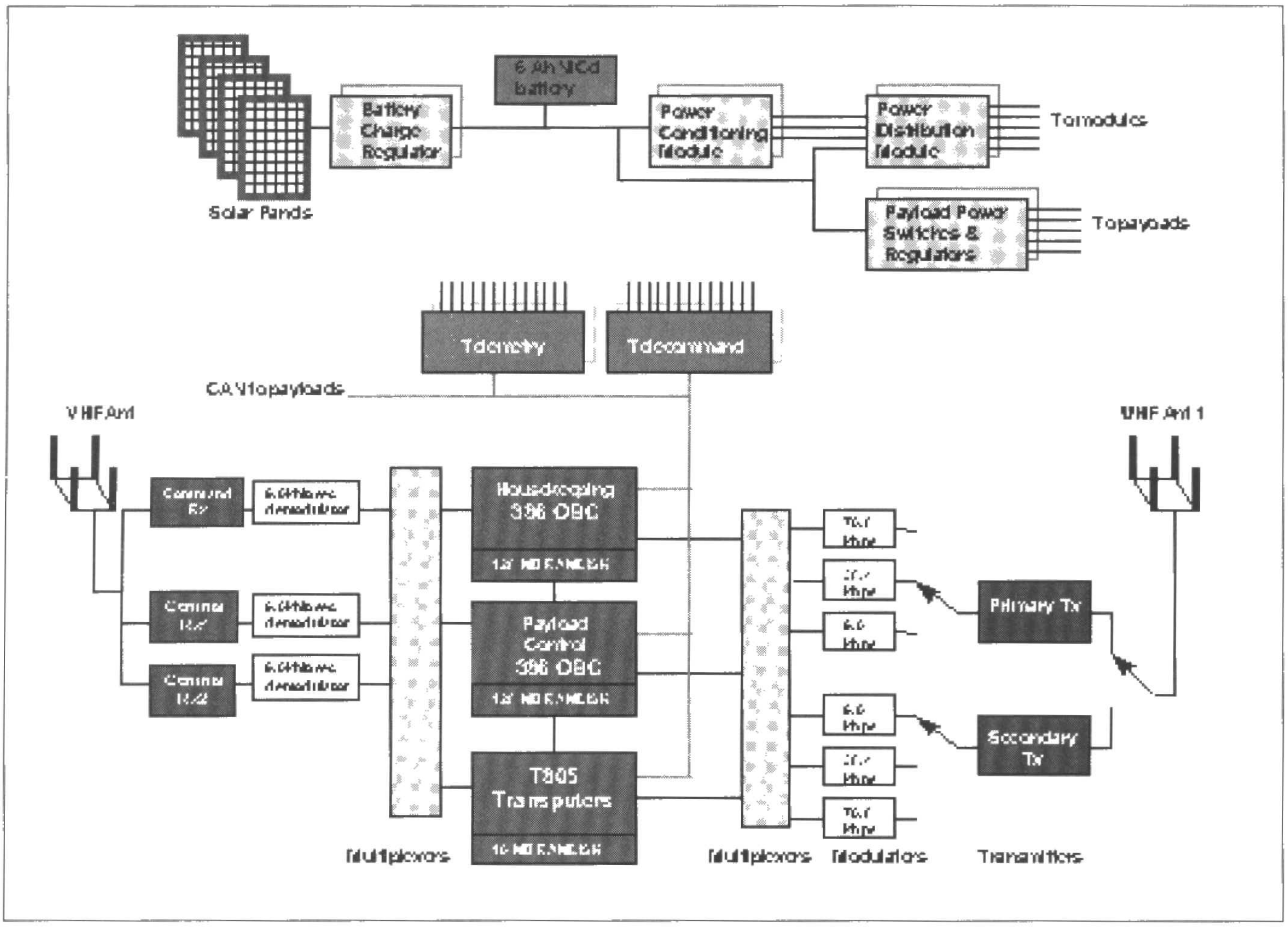
The advantages of comparatively low-cost access to space was of the greatest interest to developing nations wishing to set up their own space programmes.

The University set up Surrey Satellite Technology Ltd. in 1985(the University owns 95 percent of the company) to channel interest in their satellite programme and generate an independent income to support the University's satellite engineering research. Since UoSAT-5, all Surrey's satellites have been built for outside customers. Funds generated by the company are ploughed back into the studies of the Surrey Space Centre, which is now the largest "centre of excellence" in Europe in combined satellite engineering research, teaching and real applications. The speedy turnaround on microsatellite projects means that scientific data comes in quickly for commercial customers. As well as data-gathering in its own right, this can be used as a test-bed for the development of projects on a scale suitable for larger classes of satellite. Scientists and engineers doing postgraduate studies also benefit from the shorter time schemes possible with small satellites. A student can plan research, build data-gathering instrumentation, receive data back from orbit for analysis and write it into a thesis, all within the normal time-period of a postgraduate course.

Increasing interest is being taken in the possiblities offered by constellations of small satellites in low earth orbit (LEO) to give world-wide comms coverage via hand-held terminals, somewhat like portable amateur radio transceivers. To date there is one such constellation - of just two satellites - in full operation. HealthNet 1 and 2 (built for US network operator SatelLife) use narrow-band VHF and UHF frequencies allocated fairly recently to LEO services intended to provide digital data "store and forward" email facilities for use with small, low powered ground terminals in areas where comms cover is poor or otherwise does not exist. These frequencies experience problems in the field with multi-path propagation and man-made co-channel interference, which makes accurate information about the VHF/UHF LEO communications environment important if the most efficient modulation and coding schemes are to be chosen.



Another view of modular construction:: modles stacked to form a PicoSAT, built for the USAF.



A block diagram showing the standard SSTL microsatellite platform systems

SSTL's KITSAT-1 (Korea, 1992) and PoSAT-1 (Portugal, 1993) carry a digital signal processing experiment (DSPE), designed to provide an orbital test bed for research into optimising comms links to low earth orbit satellites. The experiment uses a TMS320C25 and TMS320C30 with prom, ram and data interfaces to the satellite's own comms, enabling it to replace hardware modems with a reprogrammable software modem. The research focuses on evaluating adaptive comms links in which the data rates, coding schemes and modulation/demodulation techniques in use are continuously optimised to suit conditions during the satellite's passing over (transit) of the ground station.

The interference characteristics of the VHF LEO frequency bands have been measured by experimental payloads carried by S80/T (Centre National d'Etudes Spatiales, France, 1992) and HealthSat-2 (USA, 1993). Working with a mobile groundstation, S80/T measured the VHF spectrum noise and interference signals to evaluate the frequencies for a full-scale LEO comms service (S80).

Gravity gradient stabilisation

Gravity gradient stabilisation is a passive means to maintain the attitude of the satellite relative to the earth. It can be considered in several different ways, the simplest of which is to say that if the satellite has a weight at the end of a long boom, and this weight is initially positioned the length of the boom closer to earth than is the satellite, then the weight will be more strongly attracted towards the earth and will stay in a downwards position. The orbit of the satellite and weight together will be that of an imaginary mass at their centre of gravity.

An equivalent way of considering it is that the boom weight is in a lower orbit than the satellite. Objects in a lower orbit complete the orbit in a shorter time than those in a higher orbit. However, since satellite and its weight must remain in the same orbit, the object in the lower orbit must travelling too slowly for its height, and has a tendency to descend, while the object in the higher orbit must travelling too fast and has a tendency to fly off into a higher orbit. The net effect is to provide a tension in the beam between the two, and a weak but effective passive stabilisation.

This works in lower orbits, but may not be so effective in very high orbits such as geosynchronous ones (at a height of approximately 35,786 kilometers).

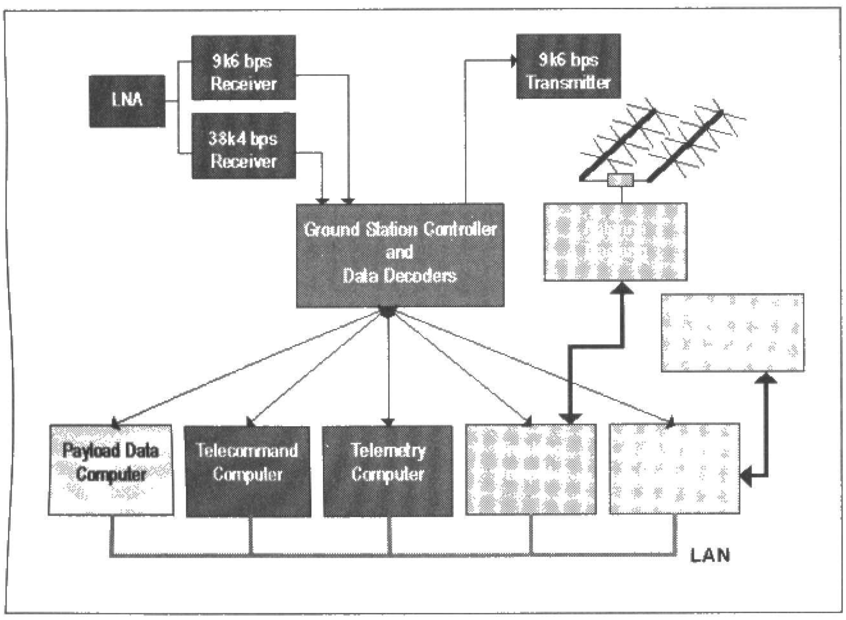
Satellites can also be stabilised by spin. However, this means that not all the solar cells can be pointed at the sun at the same time, making it more difficult to align radio antennas. Active stabilisation methods requiring frequent use of onboard propellant run into the limitation that the supply of propellant is limited.

Earth observation

Earth observation missions have traditionally been very expensive, even in mini-satellite format, costing over £150 million apiece. The development of high-density semiconductor CCDs (charge coupled devices, or solid-state cameras), used with powerful, low-power microprocessors now allows comparatively inexpensive remote sensing with smaller satellites. The early UoSAT-1 and 2 both carried the first two-dimensional CCD Earth imaging cameras, leading to a complete CCD Earth Imaging System (EIS) carried by UoSAT-5 (1991) to demonstrate the low-cost, fast response capability of microsatellites in supporting remote sensing applications. As the 2-D CCD array cameras capture single, whole images in one shot, they preserve the geometry of the area they photograph and avoiding the distorting effect of small amounts of attitude drift by the microsatellite.

The EIS on board UoSAT-5, KITSat and PoSAT microsatellites are made up from an EEV brand (UK) 576 x 578 pixel CCD digitised to standard 256 grey levels. The data is stored in 2MB of CMOS ram which can be accessed by two Transputers to allow image enhancement, and compression for storage and transmission. The data is moved via the onboard lan to the 80C186/386 system already mentioned and stored as files in the 32-128 MB ramdisk - about 60 images can be stored at once - for later transmission to the ground station. Instructions to "collect" an image of a particular part of the Earth's surface are passed by the onboard computer to the Earth Imaging System. Controllers on the ground can specify a sequence of areas anywhere on the surface of the Earth and instruct the onboard computer to collect the images according to a time and position "diary" that is uploaded to the microsatellite in advance.

PoSAT-2 carries two independent cameras, one providing a wide-field ground reslution of 2m for meteorological images, and one giving a narrow-field ground resolution of 200m for environmental imaging. Optical filters at 650 nm (+/- 40 nm) give visual separation of desert and vegetation areas, and land/sea boundaries, to provide the dramatic coloured satellite images often published. More recent SSTL satellites such as TMSAT (Thailand, 1997) support EIS cameras giving better than 100-metre resolution with three spectral bands of colour separation.



The typical SSTL mission control block diagram, showing the many computers to and from which data, control commands and progamming updates are sent during a mission

Testing technology

The SSTL PoSAT-1 groundstation in Portugal

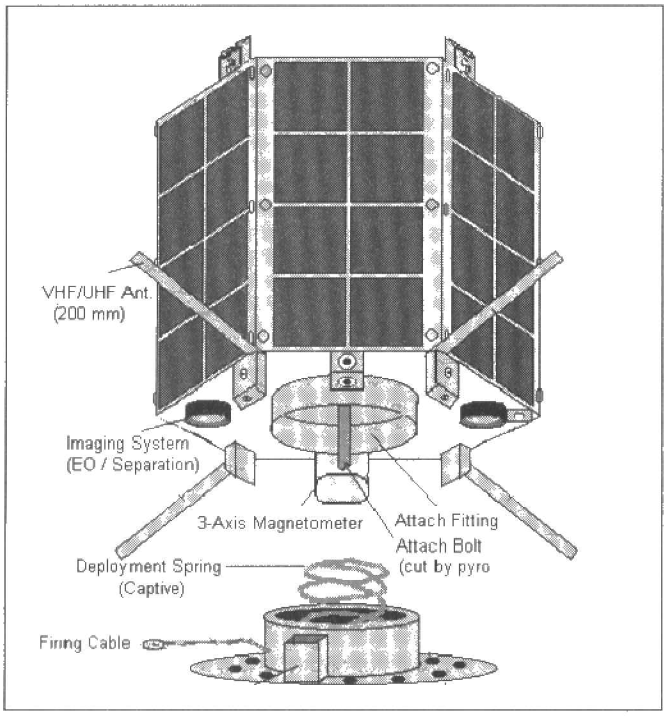
Microsatellites are useful for demonstrating and testing new technologies in orbit, where a large satellite mission would require assured experimental results to justify the very high cost.

UoSATs have carried new solar cell technologies, new VLSI devices in a space radiation environment, advanced communications and pilots of brand new communications. Testing solar cell technologies for radiation toleration within Earth's atmosphere cannot produce sufficient data to predict how the materials will stand up to the harsher radiation environment outside the atmosphere. There is no substitute for testing in orbit if any reliable predictions are to be made about the effectiveness and resilience of solar cells on larger, longer-term (and more expensive) classes of satellite. UoSAT-5 carried 27 samples of gallium arsenide (GaAs), silicon (Si) and indium phosphide (InP) from various manufacturers. All semiconductor materials and susceptible to damage by radiation, of which the sun is by far the largest source on our planet. Solar cells are therefore especially vulnerable. InP is particularly favoured for radiation resistance.

The monitoring electronics are triggered automatically when the sun passes is directly overhead of the panel in question, and measure typically 100 current/voltage points for each cell. The data, together with temperature and radiation dose data, are sent to the satellite's computer for storage for later transmission to the ground station. The greatest deterioration of the cells (and therefore the greatest number of samples taken) occurs immediately after launch.

The orbit known as Geostationery Transfer Orbit is a particularly good site to study the effects of severe radiation on components. Surrey has provided satellite subsystems and research payloads to the UK Defence Research Agency for their STRV-1 microsatellites launched in 1994.

To meet the inevitable demand for greater power at a low price, UoSat and SSTL are developing other modular satellite formats. The UoSAT-12 "minisatellite" falls in the 100-500 kg band and is based on a "platform" or design format costing around £5-8million. The cost will be greater once mission-specific systems and payload are added to the basic satellite. UoSAT-12 will carry 35-metre resolution multi-spectral and 8-metre resolution panchromatic CCD cameras. "Frequency-agile" VHF/UFH and L/S band DSP regenerative transponders will provide



The 2kg SNAP-1 "nanosatellite".

real-time and store-and-forward comms to small terminals on the ground.

Three-axis control will be provided by a combination of magnetorquers (wound coils activated with bursts of current that cause the resulting magnetic field to interacts with earth's field, and can change the satellite's attitude and/or spin rate), momentum wheels and nitrogen cold gas thrusters, and orbit trimming will be provided by an experimental electric H2O 'resisto-jet', under demonstration for possible use in future network constellations of the type mentioned earlier. UoSAT is expected to be launched into low earth orbit in April 1999.

Meanwhile, larger, better, faster, cheaper is still not to be outdone by 'smaller': a 2-kg 'nanosatellite' called SNAP-1 is being built as a research project for launch alongside UoSAT-12 in 1999. Projected applications for the nanosatellite are remote inspection of other satellites, and monitoring of satellite deployments systems in orbit.

If the future of "real" nanotechnology on a microscopic scale develops as some people believe it will, the future may experience satellites so small that they can inspect and monitor other space machines from the inside. SNAP, however, weighs around the same as a large-sized decimal bag of household sugar.

Surrey University is first and foremost and research and educational establishment, and so well placed to carry the results of its research in an educational form to clients who want to develop their own satellite programmes from a low-cost start. Happily, as microsatellites have most of the characteristics and systems of a larger satellite, but in a small package, they too are well developed for teaching and introducing the principle of space technology.

Surrey's TTT (technology transfer and teaching) programme is structured around a series of stages:

Academic education (sutiable higher degrees)
Technology traiing (secondment to SSTL)
A groundstation is installed in the client country
Microsatellites are developed: first at SSTL's own site and secondly in the client country
Technology transfer: a satellite design licence based on its technology is granted by the company to its client.

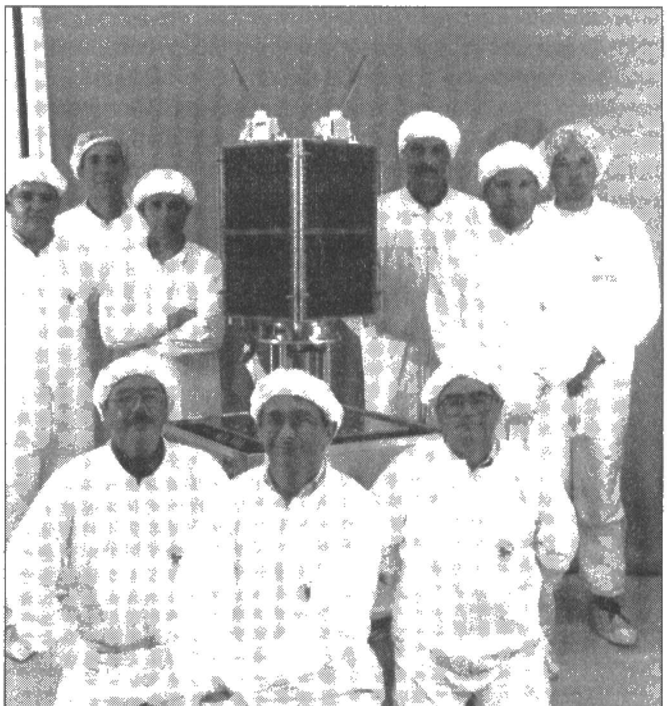
Up until 1998, six technolgoy transfers had been successfully completed by SSTL: to Pakistan, South Africa, South Korea, Portugal, Chile and Thailand. Two more, with Singapore and Malaysia, are in progress.

As we write, Surrey is preparing to welcome Her Majesty the Queen on 4th December 1998 to present the Queen's Award for Technological Achievement to the University (Surrey previously won the Queen's Anniversary Prize for Higher and Further Education in 1996). The Queen will open the new Surrey Space Centre building during her visit, and the first forum of the Surrey Space Club, a meeting point for SSTL technology transfer partners and other interested organisations to share projects and technologies, will be held on that day.

One of the most interesting aspects of SSTL's small satellite developments is the small-team philosophy that has developed of necessity outside the traditional, large aerospace organisation that normally undertakes space missions. SSTL have found that small teams of around 25 people, working closely, with well-informed and responsive management and good communications, are essential to get the projects started and completed successfully. Some of the points selected by the company are:

- personal responsibility for work rigour and quality
- well defined mission objectives
- layered, failure-resistance system architecture
- technically competent project management
- and short timescale:

...which prevents the objectives of the mission from spiralling out of control!



The technology team from Chile on the FASat-A project

Stress and skin temperature meter

Skin temperature and resistance often change as a result of stress. This meter can give you a visual and audible biofeedback indication of how stressed or relaxed you are. Handy for experimenters, therapists and lie detectors!

John Howden

Scientists have long known that skin conductivity and temperature vary with emotional stress. This unit is similar to meters used by stress therapists and hypnotherapists. It could be useful for anyone interested in:

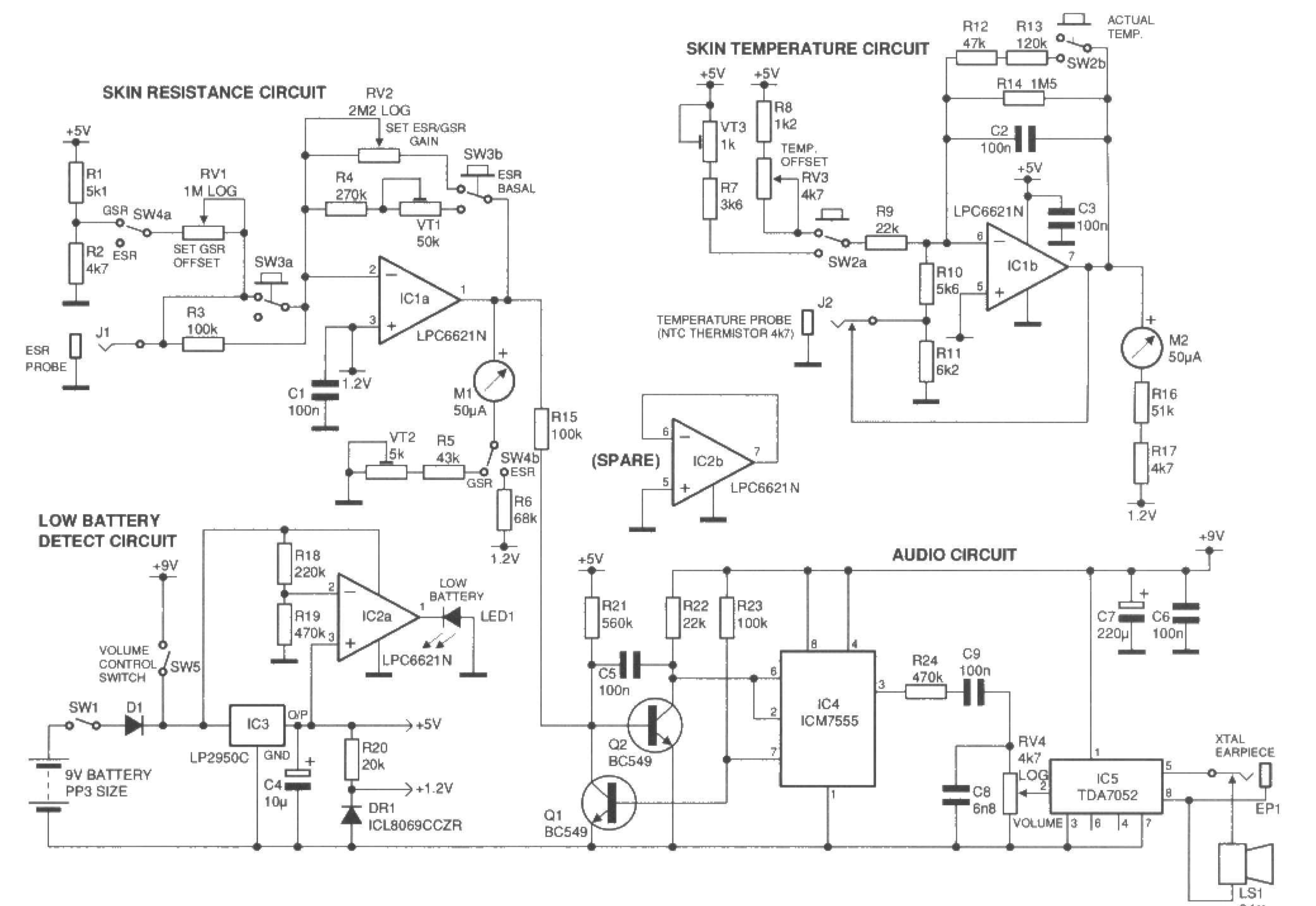


Figure 1: the circuit of the Stress and Skin Temperature Meter

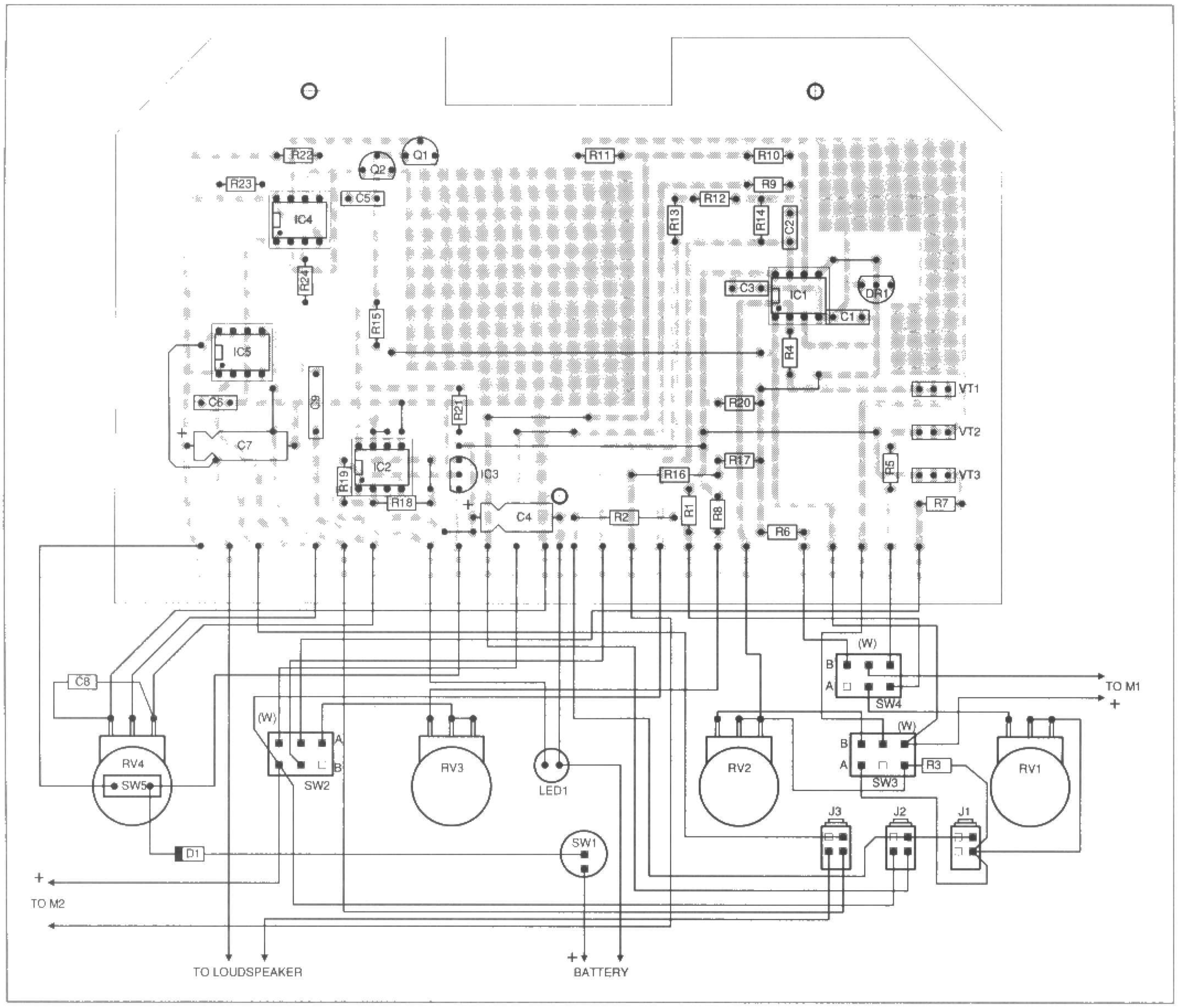


Figure 2: the component layout and wiring of the Stress and Skin Temperature Meter

Monitoring their relative level of stress
Biofeedback
Reducing stress and anxiety
Increasing self control
Improving poor circulation
Experimenting with lie detection
Monitoring small temperature changes

Nowadays exotic "mind machines" are becoming commonplace. Nevertheless the simple indications given by this meter are still useful. Likewise biofeedback, whilst no longer making headlines, remains a safe and effective way of learning to control "automatic" body functions.

Description

Two analogue meters M1 and M2 independently monitor skin resistance and skin temperature. The skin resistance reading can drive a variable pitch tone. Although digital stress meters do exist, I find that analogue displays make changes easier to follow.

The design aims included the need to make a safe device with no more than about a volt applied to the skin. I also wanted a reasonable battery life using a single battery.

The circuit (**figure 1**) has four main sections: power supply, skin temperature meter, skin resistance meter and the audio circuit.

When SW1 is on, the 9V battery feeds the audio circuit via volume control switch SW5. Diode D1 protects against accidental battery reversal. IC3 and DR1 provide regulated +5V and +1.2V for the operational amplifiers. Battery output, potted down by R18 and R19, is compared with the stabilised 5V level. If battery volts are low, comparator IC2a switches on a flashing LED.

The skin resistance and temperature circuits use similar inverting operational amplifier layouts. The 1.2V supply is used as the virtual earth of the amplifiers. Thus from the viewpoint of IC1a and IC1b, the probes are at a potential of -1.2V. This "negative" voltage from the probes is inverted, amplified and fed to meters M1 and M2. Various offset voltages or currents may be applied to back off the meter reading.

Skin temperature can be measured directly (20 to 40 degrees C) when the Actual Temperature button SW2 is held down. Otherwise the meter M2 displays the temperature change from a mid-scale initial setting. This mode has a sensitivity of plus or minus 1 degree C. Trimpot VT3 is used to set up the actual temperature range whilst the Temperature Offset control RV3 centres the needle on the sensitive range.

The temperature probe is really a very temperature sensitive resistor made from semiconductor material. Unfortunately the change of resistance with temperature is somewhat non-linear. R10 and R11 provide linearisation as discussed in a previous

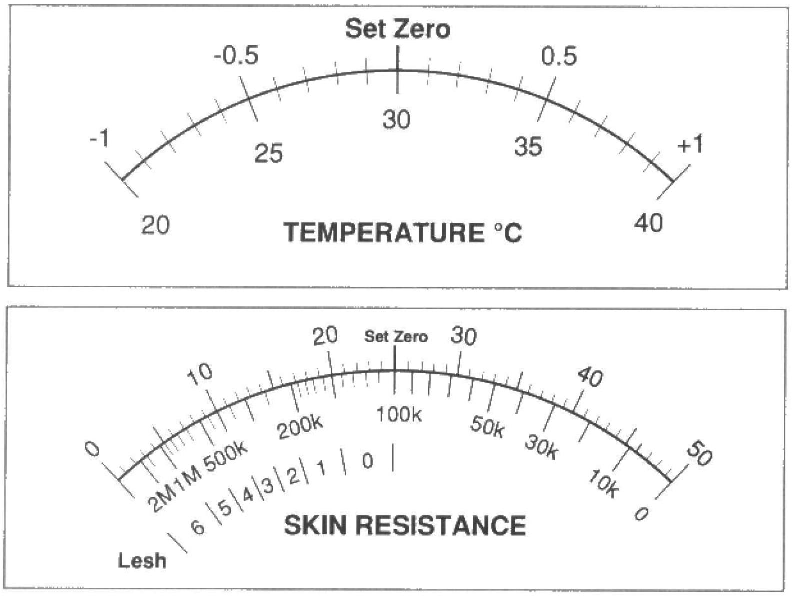


Figure 3(a and b): suggested replacement meter scales if desired

article (*Computer Aided Design on a Shoestring*, ETI Volume 27 issue 11 of 9th October 1998). With a sensitivity of 1 degree, self-heating of the temperature sensor must be considered. R10 and R11 help to minimise this effect by reducing the proportion of the 1.2V reference voltage that appears across the thermistor.

The skin resistance circuit uses conducting pads attached to two fingers. A maximum of 1.2V is applied between the pads and IC1a amplifies the resulting skin current. Meter M1 reads the output of the amplifier. SW4 switches between the two skin resistance modes ESR and GSR. ESR (Electrical Skin Resistance) mode shows actual skin resistance when the ESR Basal button SW3 is pressed. Otherwise it shows resistance changes relative to an initial mid-scale setting adjusted by RV2. GSR (Galvanic Skin Response) also shows relative resistance changes but the gain can be changed to give greater sensitivity. In GSR mode, RV2 acts as a gain control whilst offset is provided by RV1. Note that the Basal reading is meaningless in GSR mode.

The audio circuit contains a DC to frequency converter based on the 555 timer IC4. Q2, R22 and C5 form an integrator in which C5 charges at a rate determined by the output of IC1a. When the upper voltage threshold of the 555 is reached, Q1 is turned on to discharge C5 again. The pulse output from the timer is fed to a loudspeaker or earphone via audio amplifier IC5. Volume control RV4 also incorporates SW5 so that the audio section can be de-powered independently.

Warning! For safety reasons this device must NOT be adapted for mains power or connected to mains electricity in any way.

Construction

The component layout on the PCB is shown in **figure 2**. Before you begin to gather the parts for this project, first choose your meters, since everything is physically designed around them. I chose the Maplin meters to keep costs down and because they were the size I wanted. The circuit and casework is designed around these meters. A layout for temperature and skin resistance meter scales is given in **figure 3a/b** (see below for detailed insrtuctions).

As the skin resistance and temperature circuits are independent you could build only one section if you do not need both. Again, if you do this you will probably want a different layout.

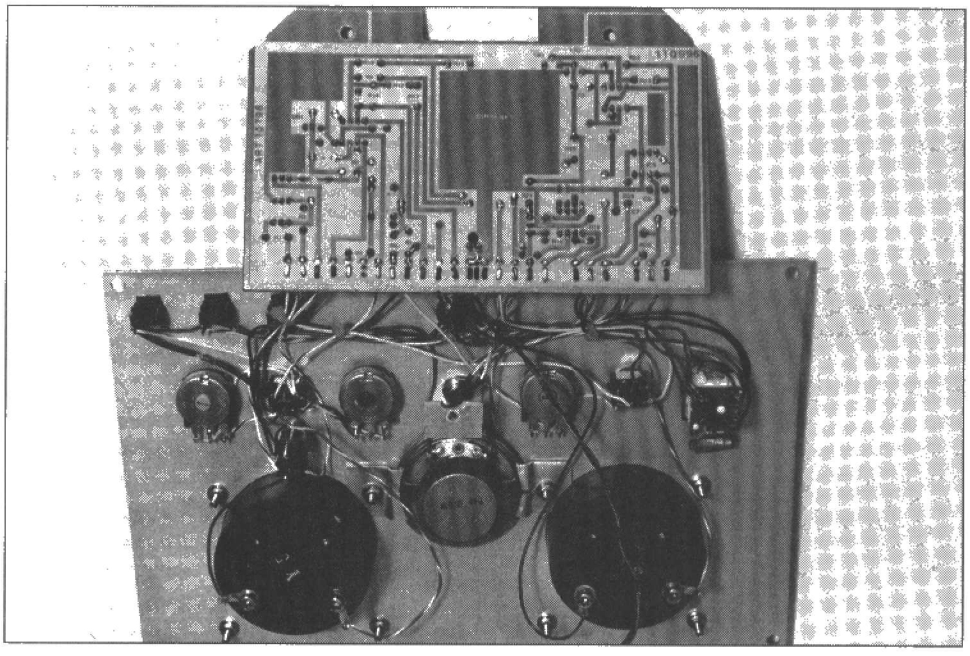
I suggest that you begin construction by drilling the front panel and temporarily fitting the meters and switches. Protect the panel against scratches during these processes. The speaker should be attached to the rear of the panel with two clips (**figure 4b/c**). Make a hole in the case for the battery box and screw it in position. The hole should be in the centre of the rear edge of the box just above the join line.

You can now check the best position for the printed circuit and drill fixing holes in it. At the top end it is supported by the meter terminals and at the bottom by a single bracket. The bracket should be made up from a strip of aluminium bent as shown in **figure 4a** and held in place by the LED bezel. Note the insulating pad on top of the bracket, which can be cut from a scrap of old printed circuit. This ensures that tracks are not shorted. Some connection should be made between the front panel and zero volts, however. I did this with a small solder tag on top of the fixing bracket, pressing on the lead of R2.

Once you are sure that everything is going to fit, dismantle the front panel again and add the lettering. I used Letraset transfer lettering and sprayed the entire panel with several thin coats of Letracote lacquer to protect it.

If you do not like to tamper with the meters the original scales can be used. It just means that reading the absolute values of skin resistance and temperature will require a conversion table. These figures themselves are not really important and most people will be happy just to watch the changes in the needle positions.

If you want to use the specific scales, first get a good photocopy of **figures 4b/c**. Remove the front of a meter by careful levering. Unscrew the two screws holding the meter scale



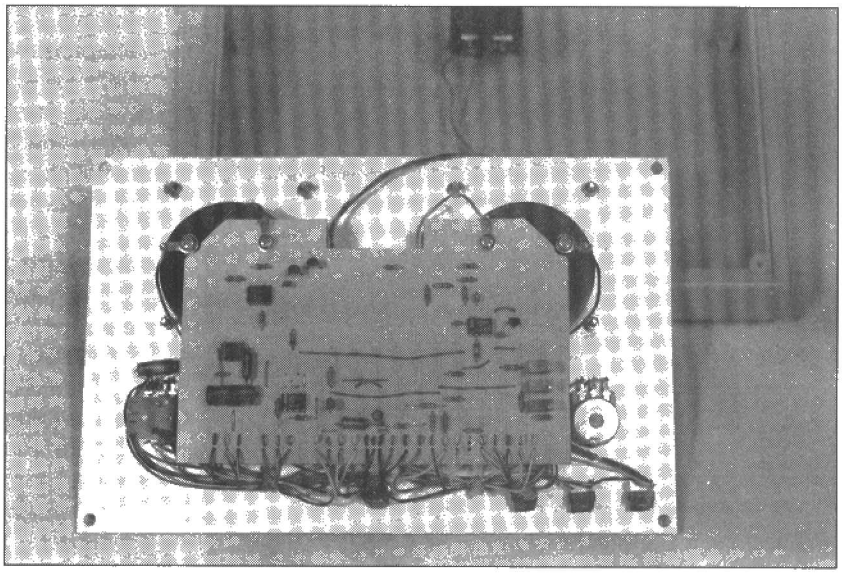
The PCB with all the external wiring strapped into place

and slide it out. It need hardly be said that this needs great care as the needle and mechanism is easily damaged. Turn over the scale, clean off the remains of any gunge used to tack it in place and glue the paper scale to the unprinted side of the metal with a non-staining adhesive. Poke holes for the screws and re-fit the scale. Re-assemble the meter taking care that the pin of the needle adjusting screw fits in its slot.

Components can now be fitted to the printed circuit. Do not forget the 12 wire links. Active components should preferably be fitted last to minimise risk of damage. The row of pads at the bottom of the printed circuit is for wire connections to the front panel controls etc. Each pad has two holes below it through which the wire should be passed for support as shown in **figure 4c**.

Finally, make up the two plug-in sensor leads. The ESR probe cable should be attached to two short lengths of strong unscreened wire at the other end from the jack plug. Each of the two wires is attached to a probe constructed as shown in **figure 5**. I used two Velcro pieces with a layer of wire wool pop-riveted to them to form the ESR probes. The rivet also passes through a solder tag to which the cable is connected. Alternative probes can be made by pressing your fingertips onto two metal plates or by pressing metal disks into the palms of your hands. Fortunately the exact means of making contact is not too critical.

For the temperature probe, sew the screened cable to the back of a piece of Velcro and fit solder tags to the two wire ends (**figure 5**). The temperature sensor is a miniature thermistor mounted in a tiny glass bead. Pass the leads of the sensor through the Velcro from the front and solder to the solder tags.



The PCB bolted down to the front panel meters and ready to be cased

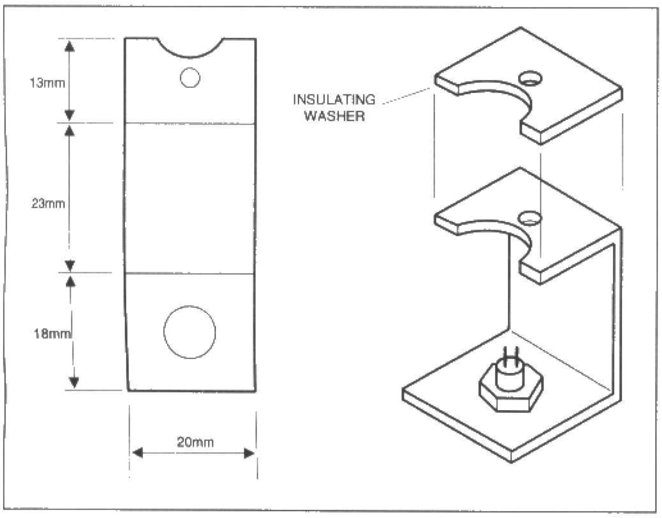


Figure 4a: the bracket to support the PCB in the case

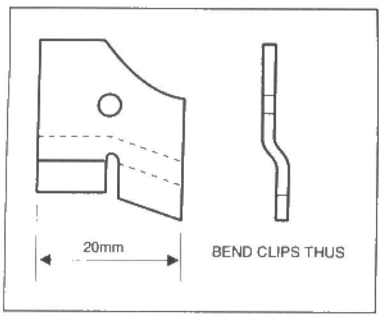


Figure 4b: making the speaker clips

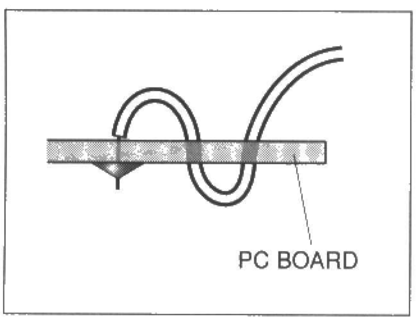


Figure 4c: wire locking on the offboard wiring pads

Sew the tags to the Velcro and cover with more Velcro. Finally attach a small piece of the complementary Velcro so that the material will form a band around a finger and hold the bead in contact with the fingertip. Connect the far end of the cable to a jack plug.

Calibration and testing

Set all potentiometers roughly mid-range and check the 5 V and 1.2 V supplies, also that the main circuit sections are doing something sensible. If all is well you can proceed to calibrate the system. The sound can be turned off while this is done.

The temperature circuit has only one adjustment, which sets the reading of actual temperature. Put the temperature probe in a dry environment where the temperature is stable between 20 and 40 degrees Celsius (a hot summer day will suffice). Read the ambient temperature with a conventional thermometer. Press the Actual Temperature button and adjust VT3 until M2 reads the same temperature on the lower scale.

The skin resistance circuit has two trimpots to set. Switch SW4 to ESR mode, press the ESR Basal button and short circuit the ESR probe. Adjust VT1 to get a maximum meter reading on M1 (0 on the resistance scale).

With SW4 set to GSR (do NOT press the Basal button), connect a fixed resistor of around 100k across the ESR probe. Use RV1 (Set GSR) to bring the needle of M1 to its central Set Zero position. Adjust VT2 until the meter reading will remain central when RV2 (GSR Gain) is varied over its entire range.

This completes the setting up. Further checks may be carried out to ensure that everything is working fully. With no temperature probe fitted the needle of M2 should rest gently at the extreme left of the scale. When turned on, the pitch of the sound should rise from a very low note when M1 needle is at the left of the scale to a high note when it is at the right.

Operation

To use the ESR function, connect the finger probes to two fingers of one hand. It helps to get good contact if the hands are rubbed together first. The contact must be on the soft part of the fingertip. Plug the ESR probe lead into the ESR jack socket J1. Set the GSR / ESR switch SW4 to ESR. Switch on the meter.

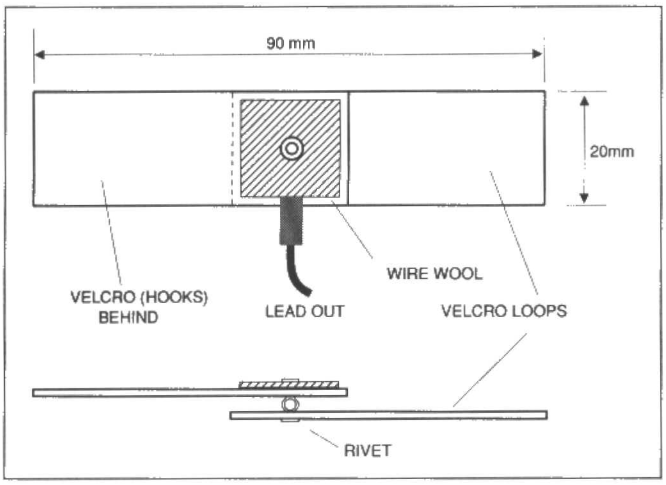


Figure 5a: construction of two ESR finger pads

To check absolute skin resistance, press the ESR Basal button SW3. Read the resistance in k ohms or M ohms on meter M1 bottom scale.

To monitor changes in ESR, release the button and adjust the Set ESR / GSR Gain knob VR2 until the meter needle is at mid-scale. Afterwards any increase in reading indicates greater stress, reduced readings more relaxation. If you want to use sound, turn it on as described shortly.

If the skin resistance is exceptionally high, it may not be possible to get the needle to the mid-point. In this case check the following:

Are the hands too cold or dry? Rub the hands together again.
Are the finger contacts tight enough?
Is the hand still?

If the skin resistance is still high you will have to work with whatever meter offset you can get, or try using GSR.

The GSR function is similar to ESR. Connect the skin resistance electrodes in the same way. Set the GSR / ESR switch to GSR and switch on. Do not try to read basal resistance in GSR mode, as it will give invalid results. RV1 and RV2 are used in combination with each other. The Set ESR/GSR Gain control becomes a gain control. The more it is turned clockwise, the more sensitive the meter will be to changes in skin resistance. The meter needle is set to mid-scale as in ESR mode but using the Set GSR knob as back-off control. You may find it easiest to reduce the gain to a low value initially, balance the meter, then increase the gain and make final small adjustments to the balance. If the skin resistance is fairly high it may not be possible to increase the gain above that in the ESR mode.

The sound generator is connected to the skin resistance channel only. It has its own on-off switch on the volume control to help extend battery life. When RV4 is turned clockwise you should hear the tone through the built-in loudspeaker. Frequency increases with deflection of the M1 meter needle. For prolonged biofeedback use it may be better to use an earpiece or earphones connected to jack socket J3.

The Temperature function may be used separately from the skin resistance functions or at the same time. Strap the temperature probe to one finger ensuring that the glass bead makes good contact with the pad of the finger. Connect the probe cable to the Temp socket J2 and switch on the meter.

Pressing the Actual Temperature button SW2 displays the probe's temperature in degrees centigrade on meter M2's lower scale. The probe will probably take a minute or two to reach finger temperature. Release the button and adjust the Temp Offset control RV3 to bring the meter needle to mid scale. Small changes in finger temperature can now be monitored using the top scale.

Applications

Therapists should know many ways to use this device. I will describe a few that could be of interest to the non-specialist.

The ESR facility gives a useful indication of the state of your autonomic nervous system: how stressed or relaxed you are. High stress or over-arousal is likely to be signalled by one or more of the following:

A basal resistance of less than about 50k
Large (30 percent full-scale) needle swings to the right on perceiving a threat, being suddenly alarmed or recalling frightening events.
The needle taking a long time to recover the mid-position after such a movement.

Conversely, a high basal resistance and/or needle slowly moving to the left of centre usually signify relaxation or lack of arousal. The exception might be a basal reading above roughly 500k, which could be just due to bad contacts or cold hands. Other reasons for such a high resistance might be depression, (prescription) drug effects or regular meditation. Do not put too much significance on this absolute resistance; more important is how it changes over a number of sessions.

Many people want to relax more but do not know how to do it. To use the meter to help you relax, connect the finger pads and sit or lie down comfortably where you can see the scale. Press the ESR Basal button and note the resistance reading for future comparison. Release the button and centre the needle with the Set ESR control. Now experiment with physical position, breathing and thoughts to see what makes the meter change and in which direction. You should aim to get the meter to slowly drift to the left, the further the better. There is no space here to explain the Lesh scale on the meter but if the needle moves from 0 to 6 you are doing exceedingly well. A movement from 0 to 3 would be more typical.

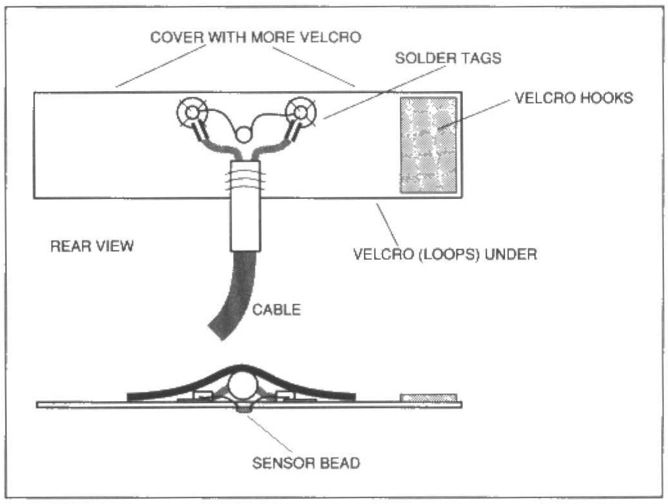


Figure 5b: construction of temperature probe

Watching the meter can be a problem, especially if you are lying down or want to close your eyes. This is where the sound facility comes in. Aim for the lowest tone.

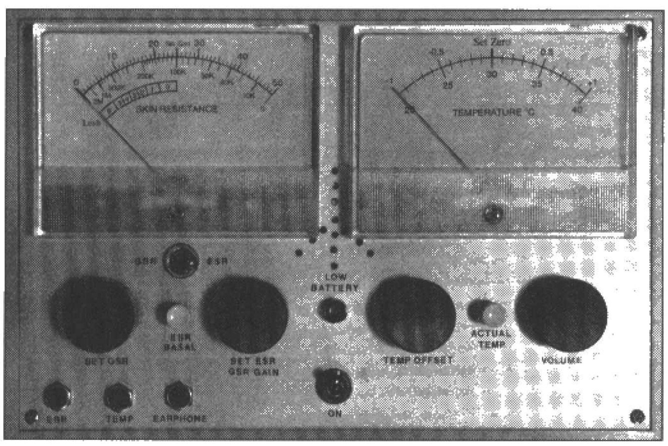
Here are some hints for getting good relaxation. Pay attention to your breathing and slow it down while at the same time making it deeper. Your stomach should rise with each inhalation. Try breathing so that there is a smooth change between the in-breath and the out-breath. Concentrate on each part of your body in turn, moving mentally from head to toes or the opposite. Notice the tension in various muscles, especially around the mouth, neck, chest and solar plexus. Where you become aware of tension, let it go. It may help to purposely tense each muscle for a few seconds before relaxing it. When your body is comfortable, relax your mind by visualising a pleasant scene such as a garden. Use all your senses. What would you see, hear, feel and smell if you were there?

When you begin to get results with the ESR, try adding the temperature meter as well. As you relax you should find your finger temperature rises slightly due to increased blood flow to the skin. The changes will probably be slower and less pronounced than with the ESR.

Raynaud's syndrome is a condition in which blood flow to the fingers or toes is reduced below normal. Arthritis can also lead to circulation problems. Whether or not you are a sufferer it can be interesting to see how much you can change your finger temperature by using your imagination! For example, set the temperature meter needle to mid position and imagine your hand in a bucket of ice. What would you be seeing, feeling and perhaps saying to yourself? After a few minutes check the meter reading. Did it change? Try also imagining holding your hands in front of a warm fire and so on.

It can be fun to experiment with using the meter as a "lie detector". In theory the person being tested will be more stressed when telling a lie. The extra sensitivity of the GSR can help here. Be aware of the couple of seconds' delay between answer and needle movement. Operators of commercial lie detectors calibrate their machines by asking questions in which the subject is asked to tell the truth or to lie about simple facts such as their name. Of course such detectors monitor a large number of body parameters and plot the results on a long chart.

Biofeedback is an extension of some of these experiments. It is a way of gaining control over a body function by using visual, audible or tactile feedback. Thus this meter lets you experiment with controlling your autonomic nervous system and your skin temperature. So far I have being giving you hints of how to achieve changes but in biofeedback you simply keep watching or listening to the meter whilst staying aware of the desired result. Most people find that after a few hours of training they can control the function without being aware of exactly how they do it. Have fun and - just relax!



The finished front panel with replacement meter scales

PARTS LIST *for the Stress and Skin Temperature Meter*

Resistors

(All 1 percent, 0.6W metal film)

R1	5k1
R2, R17	4k7
R3, R23, R15	100k
R4	270k
R5	43k
R6	68k
R7	3k6
R8	1k2
R9, R22	22k
R10	5k6
R11	6k2
R12	47k
R13	120k
R14	1M5
R16	51k
R18	220k
R19, R24	470k
R20	20k
R21	560k

Potentiometers (panel mounting)

RV1	1M log
RV2	2M2 log
RV3	4k7 lin
RV4/SW5	4k7 log, with switch

Trimpots

(22 turn Cermet)

VT1	50k
VT2	5k
VT3	1k

Capacitors

C1-C3, 5, 6	100nF ceramic
C4	10uF 25V
C7	220uF 16V
C8	6800pF polystyrene
C9	100n polyester

Semiconductors

IC1, IC2	LPC662IN op amp
IC3	LP2950C voltage regulator
IC4	ICM7555 timer
IC5	TDA7052 audio amp.
Q1, Q2	BC549
D1	1N4148
DR1	ICL8069CCZR 1.2V reference diode
LED1	5mm yellow flashing LED

Miscellaneous

SW1	Toggle switch SPST
SW2, SW3	Push switch DPDT momentary
SW4	Toggle switch DPDT
J1-J3	Jack socket 3.5mm mono

Jack plugs to match
Buttons for push switches; knobs, 28mm diameter
Crystal earpiece 3.5mm, 8 ohm
LS1 loudspeaker 64 ohm, 2in (or 49mm) diameter
Single core screened cable, 2 metres
Finger contacts (see text)
Console box, style 4 (Maplin YN30H)
Panel meters, 50uA (Maplin RX54J)
PP3 battery holder (Maplin MJ45Y)
Chrome bezel for LED (Maplin FM38R)

The components in the Parts List are generally available and most are stocked by Maplin. Order codes are given for the following components that could cause difficulty.
The 4k7 NTC miniature bead thermistor is available from Electromail part number 151-142
Electromail also stock double pole push switches.

Switch-Volt PSU

Terry Balbirnie

This no frills power supply will provide power for most circuits built in the home workshop.

Commercial bench PSUs often cost more than is strictly justified by the home constructor's needs, especially the more strapped constructor. They frequently deliver a continuously variable output from 0 to 30V at up to 3A whereas we are usually working with up to 12V at a maximum of 250mA or so.

Mains is potentially dangerous. If you do not have the appropriate mains construction experience, please seek the assistance of an experienced constructor.

Modest requirements

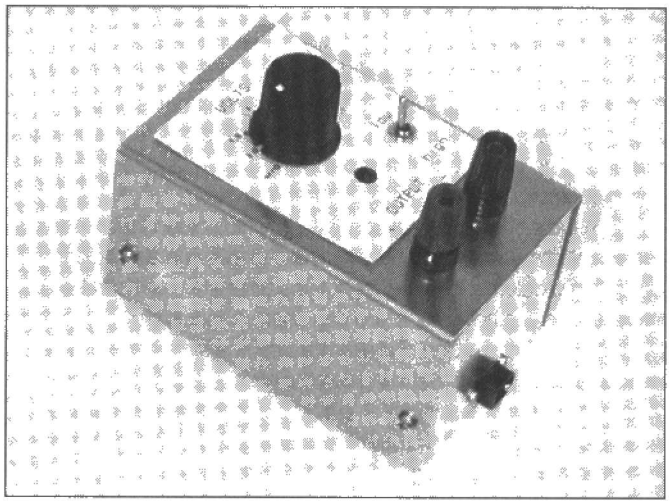
For example, the power supply does not need a continuously variable output for battery-operated circuits. It's more convenient to have switched voltages corresponding to two, three, four, six and eight 1.5V cells, that is, a nominal 3V, 4.5V, 6V, 9V and 12V. The 12V output is suitable for small automative circuits. Another spin-off is that there is no need for a voltmeter on the panel, further reducing the cost and size of the unit.

The output current is electronically limited to either 300mA (high) or 100mA (low) according to switch setting, so a fuse is not needed. The current available at the output terminals will usually be a little less than these figures, due to the LED output indicator. This will be explained in more detail later. Even if a short circuit is applied to the output terminals indefinitely, the circuit will come to no harm.

Power for the circuit is provided by a commercial plug-in mains adaptor, avoiding the need for a transformer inside the unit. For safety, the adaptor must be a high-quality type. You will need a multi-tester during setting-up, to check that the output voltages and current limits are within design limits and that there are no construction mistakes.

Overview

The prototype is housed in a small aluminium box. The plug-in adaptor will be connected to a power-in socket on the side. The output voltage/on-off switch is on the top. A toggle switches the current limit between high or low. An LED



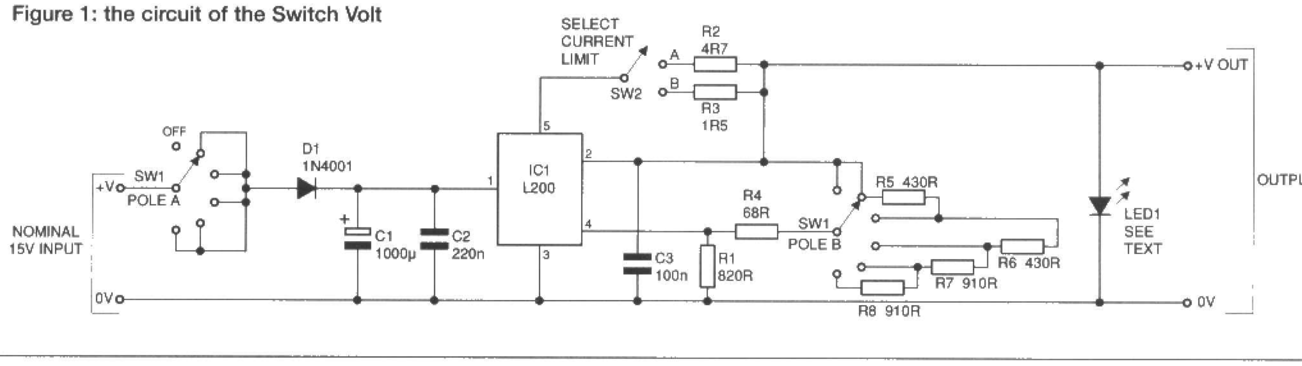
indicator both confirms that the circuit is operating, and indicates a short-circuit condition or an attempt to draw excessive current, by going out. A pair of terminals connect the circuit on test.

How it works

Figure 1 is the circuit of the power supply. A nominal 15V dc input is derived from the power adaptor, which can be a simple non-regulated type rated between 300mA and 500mA. You could use a 12V unit, but in that case the 12V output would not be available. This might be useful to readers who already have a good-quality scrap 12V adaptor retrieved from some piece of discarded consumer electronics. **Note that the mains adaptor must give a smoothed dc output - it must NOT be an ac type, which is just a straight transformer and is unsuitable.**

When rotary SW1 is off, pole A prevents current flowing. If the switch is set to any of the other five positions, current flows to the circuit via D1, which provides reverse-polarity protection. Some plug-in adaptors suffer from poor smoothing, so C1 is included to improve this.

Figure 1: the circuit of the Switch Volt



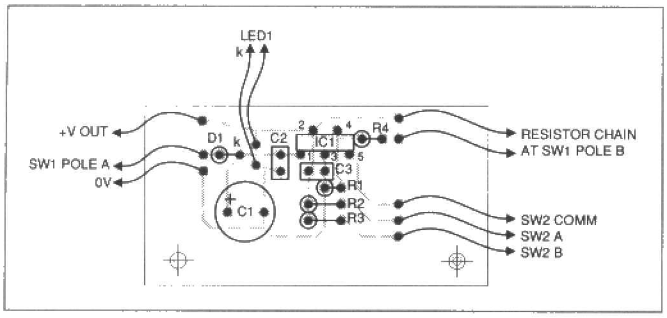


Figure 2: the component layout of the Switch Volt

Programming guide

With SW1 on, the 15V supply is connected to the input (pin 1) of IC1, the voltage and current regulator. This is programmed to give the required output voltages and current limits by connecting various external resistors to it.

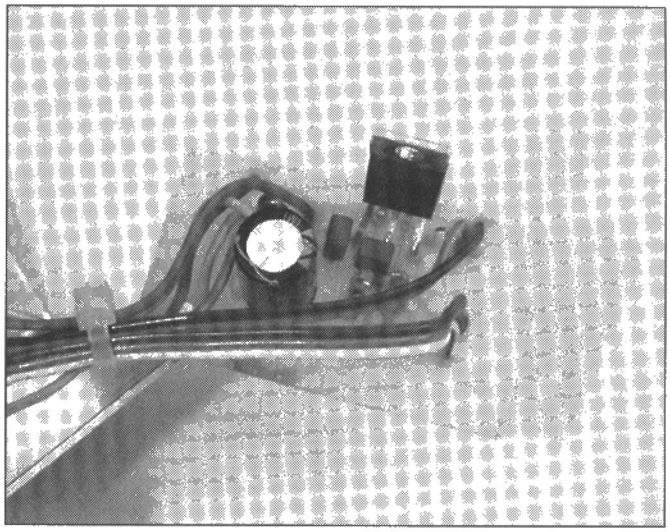
Looking at voltage regulation first, the output voltage is related to the value of R1 (between pin 4 and the 0V line) and the resistance appearing between pins 2 and 4. R4 is always in circuit, together with a further resistance set by the position of SW1. Pole B has R5 to R8 connected between its tags (as in figure 3). These are chosen to provide the required nominal output voltages at the various positions on the switch. Pole B position 1 is unused (although it is connected to the "3V" one for a reason explained below). This is the off position as set by pole A. With SW1 set to 3V, there are no resistors switched in, and the total resistance between IC1 pins 2 and 4 is simply R4. As the switch is advanced, further resistors come into series, giving 4.5V (R4 and R5), 6V (R4, R5 and R6) and so on up to 12V with all resistors from R4 to R8 connected. SW1 pole B "off" is connected to the 3V position so that (perhaps during testing when the supply may be connected direct rather than via SW1) the path between pins 2 and 4 is never left open-circuit, which would lead to the output rising to virtually the full input voltage. R5 to R8 are soldered direct to the switch tags, rather than mounted on the PCB, to reduce the amount of hard wiring.

Although the resistors at SW1 are chosen to provide near-correct values for the output voltages, these must be regarded as nominal, as the resistors are the nearest 1 percent tolerance values available off the shelf. Also, the voltage at the output is dependent on a certain reference voltage built into IC1, which is subject to its own tolerance. Despite these approximations, the voltage outputs in the prototype all fell within 1.5 percent of their stated values, which is more than adequate for most purposes.

To the limit

Current limiting is achieved by connecting a fixed resistor between IC1 pins 5 (the output) and 2 (the limiting input), either R2 or R3 according to the setting of two-way SW2. The values are chosen to give a nominal 100mA (Position A) and 300mA (Position B). However, the LED connected to the output requires its own current, which pulses as the LED flashes. The available current is therefore somewhat less than the values given, as stated previously.

In the current limiting part of the circuit, the output current flows through either R2 or R3, developing a voltage. When this tends to rise above 0.45V (which is a reference value set internally by the ic) the voltage appearing between pins 1 and 5 is reduced to maintain it. The current limit is a nominal figure, because the 0.45V reference voltage has a tolerance of about 15 percent.



The on-board components

C2 and C3, connected between IC1 pins 1 and 2 respectively, and the 0V line, decouple IC1 input and output and provide stable operation. LED1, connected directly across the output, is the ON indicator. No conventional series resistor is needed because current-limiting takes place on a built-in chip. This provides about the same brightness for any of the output voltages appearing across it. I have used a flashing kind, because non-flashing LEDs with a constant-current chip seem to have disappeared from the market. The LED will also show when the output terminals are short-circuited or connected to a low-resistance path by going out when the voltage falls below the 3V level needed to operate it.

With the unit delivering its maximum current and set to 3V, there will be about 12V (15V -3V) between IC1 pin 1 and the positive output terminal, giving a dissipation of around 4W. When the output is short-circuited, the entire 15V will appear between IC1 pin 1 and the output, and the power dissipation will be about 5W. IC1 must therefore be fitted with a heatsink, otherwise the ic would overheat and its thermal shutdown facility would switch in. In the prototype, the heatsink was the enclosure itself. With the aluminium box specified, it did not become excessively hot even with a prolonged short-circuit applied to the output terminals.

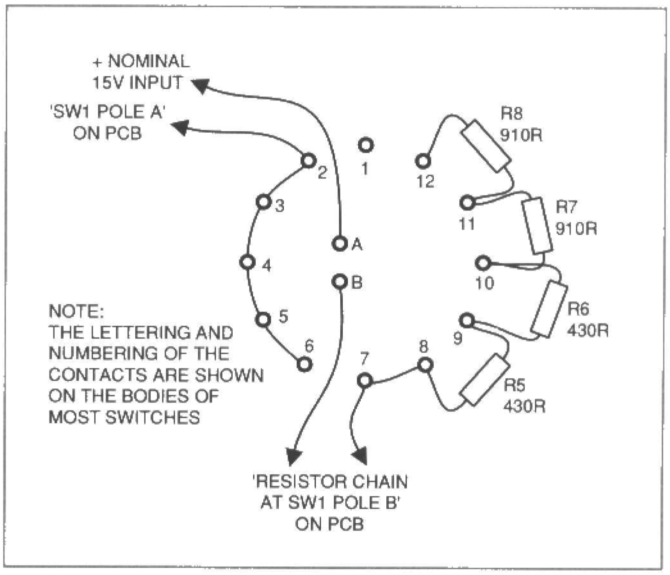
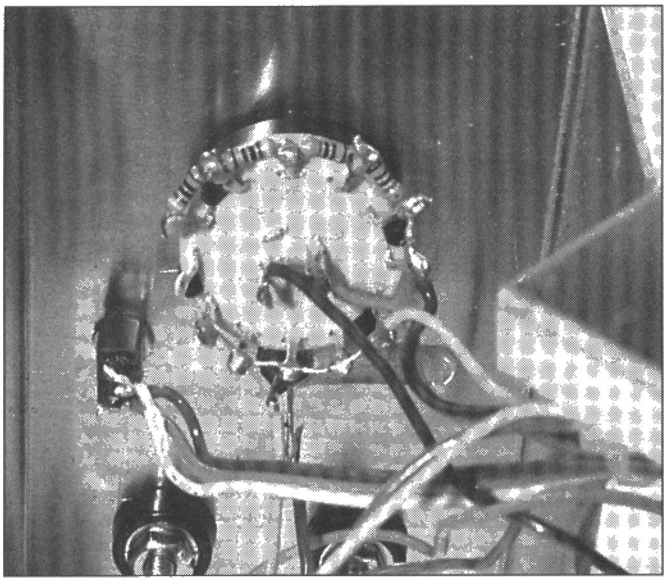


Figure 3: connecting the wires and resistors to SW1



The resistors and wiring mounted on rotary SW1

Construction

Figure 2 shows the component layout. Begin by drilling the two fixing holes. Solder in R1 to R4 and C2 and C3, followed by D1 and C1 taking care with the polarity. Solder pieces of light-duty insulated wire to the points labelled "+Vout", "SW1 pole A", "0V" and "Resistor chain at SW1 pole B" and the three wires (comm, A and B) for SW2. Solder connecting wires to the pads for LED1. Finally, add IC1 with its metal backing towards the outside (see photograph).

If you are using the case as a heatsink, the metalwork should be electrically floating, that is, not connected to either input or output wire. A good-quality plug-in adaptor should not readily suffer internal failure leading to one of the output wires becoming "live". However, keeping the case unconnected prevents short-circuits should the "wrong" output wire accidentally touch the case during use.

Holding the PCB against the base of the box with the tab of IC1 in contact with the side, mark the position of the mounting holes and drill them. Drill holes in the top for the switches and output terminals and in the front for the power-in socket. The socket must be fully-insulated (plastic body) with neither terminal connected, to allow the case to float. Attach SW2, the input socket and the terminals. The terminals must be mounted using the plastic bushes supplied with them, to prevent any electrical contact with the metalwork. Mount the PCB using 12mm long plastic stand-off insulators on the bolt shanks to raise the solder joints above the base of the box. Mark the position of the hole in the ic. Remove the PCB and drill this hole. Re-attach the PCB and secure the ic using a small nut, bolt and a mounting kit. The mounting kit (consisting of a mica or similar washer and a plastic bush) ensures that the tab of the ic does not make electrical contact with the case (it is connected internally to the 0V line). Again, this keeps the case floating. The washer material has a high thermal conductivity and does allow the free flow of heat.

Your break

SW1 must be a make-before-break type. A break-before-make switch would allow the voltage at the output terminals to rise to virtually the full input voltage between positions. This would happen instantly as the switch was moved between its various settings. This could be disastrous to a circuit connected to it - you have been warned! As a precaution, always pre-set the switch to the correct output voltage in use. It should then be checked with a multi-tester before connecting a circuit.

Prepare SW1 by soldering the resistors and link wire to its Pole B tags as shown in **figure 3** and the photograph. Solder the link wires at Pole A tags. The numbering and lettering is as shown on the body of most switches. Solder pieces of wire to the four points indicated. Mount the switch and, referring to **figure 4**, complete the internal wiring apart from that of the LED. In the prototype, the pin (centre) connection of the input socket was used as the positive one. However, this will depend somewhat on the plug-in adaptor. If it has a fixed output polarity, this should

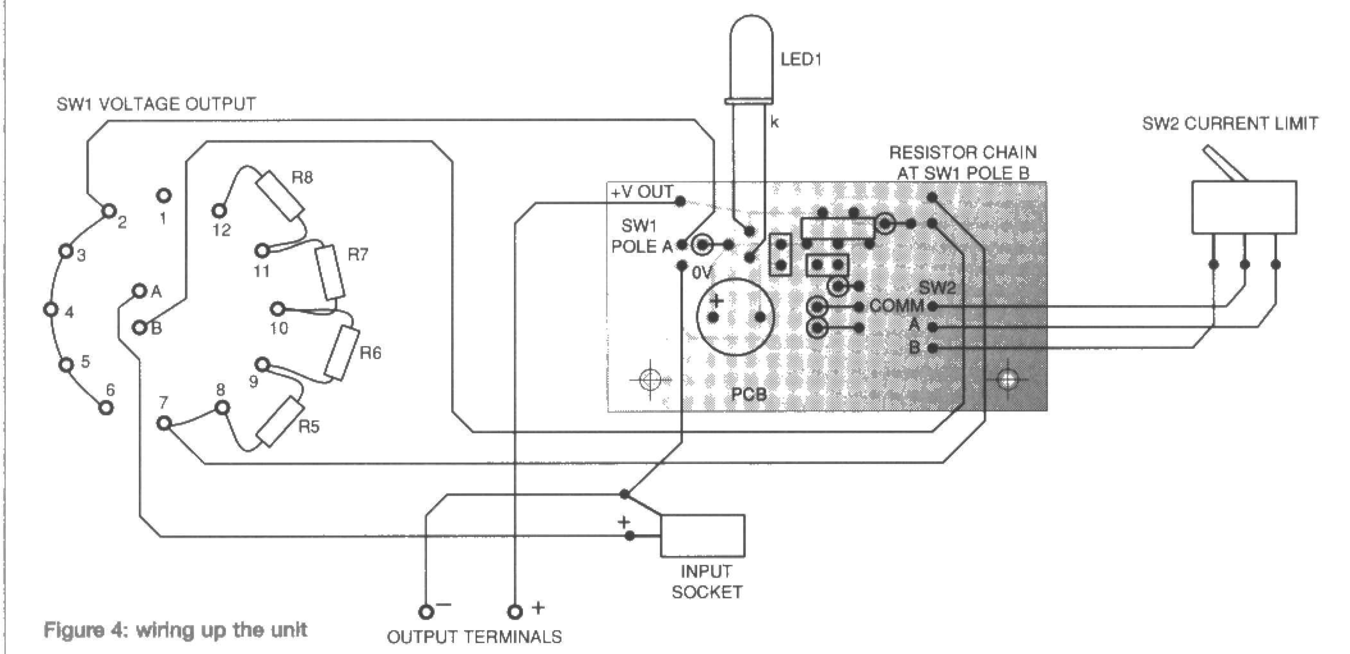
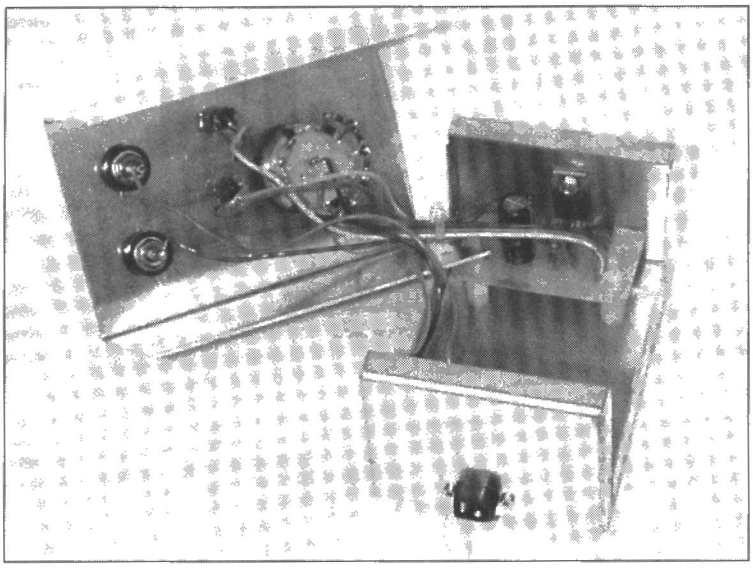


Figure 4: wiring up the unit



The board and offboard components mounted in an aluminium case

be made to match that of the input socket. Many units have a polarity-reversing plug and socket in the output lead so the polarity of the input socket does not matter. Remember, no harm will result if the supply is connected in the wrong sense. If the unit fails to work at the end, it will be simply reversed.

Cut the LED wires to about 10mm, keeping note of which wire is which. Using minimum necessary heat to avoid damage, solder the connecting wires from the PCB to the LED, observing the polarity. In the prototype, the LED is the "lighthouse" type because that was the only type available. Decide how you want to attach it, and drill a hole for it in the lid. I neatened the appearance of it with an LED clip. This will not accommodate a "lighthouse" LED, so I cut off the top part with only 1mm or so of the lugs protruding. It was then secured in position using a little quick-setting epoxy adhesive. The LED was fixed in the clip with a little of the same. Separate the soldered joints to make sure the bare wires cannot touch one another or anything else. If there is any chance of this happening, use some heat-shrinkable sleeving on the wires. Fit plastic feet to the base of the box to protect the work surface, but do not fit the lid yet.

Testing

Set SW1 to off and the current limit to 100mA. Switch the multi-tester to a suitable dc voltage range and connect it to the output terminals. Plug in the power adapter. Set SW1 to "3V" and check that voltmeter is reading very close to this figure. Repeat for each voltage setting. All the readings should be within about 2 percent, for example, the nominal 12V output should lie roughly between 11.8V and 12.2V.

If all is well, check the current limits. Set the multi-tester to a suitable current range and connect it directly to the output terminals. If the circuit is working correctly the reading should be about 100mA. Repeat for the 300mA limit. Note that the LED goes off under these circumstances. Since it not conducting, the full output current is available at the terminals.

Unplug the power adapter and fit the lid. Re-connect and apply a short circuit to the output using the 3V setting and a 300mA limit. **Leave it like that for ten minutes, checking at intervals that the case does not become excessively hot**. If there are any problems with overheating, provide some ventilation by drilling a few holes. This was not needed on the prototype.

When everything is working correctly, all that remains is to make a label for the top panel and put the power supply into service. Make it a rule to set the voltage and check it using a multi-tester before connecting the circuit. Do not change the voltage switch setting while a circuit is in place.

PARTS LIST *for the Switch Volt Power Supply*

Resistors

All resistors 1 percent metal film for best results

R1	820R
R2	4R7
R3	1R5
R4	68R
R5, R6	430R
R7, R8	910R

Capacitors

C1	1000u 25V
C2	220n ceramic
C3	100n ceramic

Semiconductors

IC1	L200CV
D1	1N4001
LED1	3mm red flashing LED (see text)

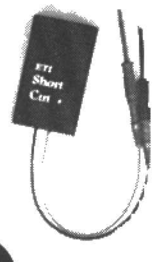
Miscellaneous

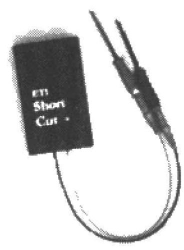
SW1	2-pole make-before-break 6W rotary switch
SW2	SPDT miniature toggle or slide switch
SK1	Fully-insulated 2.4mm chassis-type "power-in" socket - see text.

Good quality unregulated plug-in power adapter: 15V dc nominal output at 300mA minimum (see text).

PCB materials; TO220 mounting kit; small terminal posts, one red; one black; aluminium box 102 x 64 x 51 mm.

The 'Short Cut' Versatile Continuity Tester





Andrew Armstrong

This versatile, small tracer helps to locate short circuits, works as a conventional continuity tester and will unambiguously tests diode junctions. It can also test double diode junctions such as Darlington transistor base connections.

This project is designed specifically to help find short circuits. It is often easier to discover that two tracks are shorted than it is to find out where the short is. This tester is designed to respond to changes in very low (sub-1ohm) resistances, so that it can indicate which part of the track has the short.

This continuity tester has been designed to be as versatile as possible, which means that it has rather more circuitry than simply a battery and a buzzer. To make it small enough and light enough to be useful it is designed using surface mount components, and it can run on two AAA cells if used in conjunction with the power supply project from last month. Otherwise, any 5V supply that can provide at least 60 milliamps and is at least approximately regulated (4.5 - 5.5 volts, for example). Alternatively, four AA or AAA-size cells in series will provide power with a slightly inferior performance; in this application these must be replaced promptly when they begin to run down. Obviously, a different power source will affect the choice of case.

Audible indication

Testing for continuity is more difficult with an ohm meter, partly because holding the probes in place requires you to look at the pcb under test instead of at the meter. A variable pitch audible indication of resistance, on the other hand, is very useful when changes in resistance rather than the absolute value of the resistance must be measured. In this design, the frequency decreases as the resistance decreases, with a high frequency indicating one or two diode junctions or a high resistance.

This device gives a frequency depending on the resistance between the two probes, up to a maximum of about 3.5R with the component values used here. It would be possible to increase the sensitivity to low resistance by increasing the current fed to the probes, but the battery life would be reduced. There is a limit to how much the current can be increased before the dissipation in Q2 or R2 reaches its maximum limit.

Clearly, the limit of 3.5R would perhaps make the sensitivity too low when searching for a short circuit between two large thick tracks, but is reasonable when tracing over thin tracks. In the normal course of events, a thin track is more likely to be

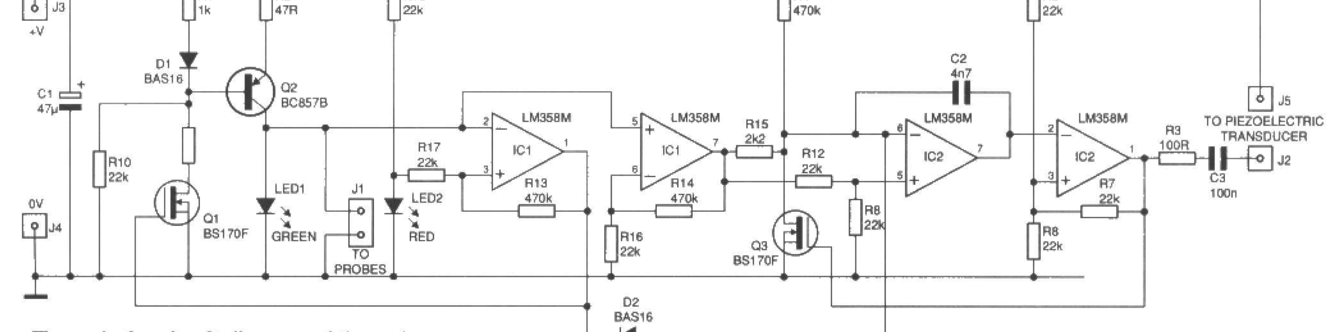


Figure 1: the circuit diagram of the pcb

running close to another thin track, and therefore at more risk of shorting. This is also the situation in which it is most difficult to find the short circuit by visual inspection. For this reason, the component values in this design are believed to be the most widely suitable, but other values might be useful in more specialised applications. Some alternative component values, chosen to give the maximum possible current without exceeding component ratings, is offered for readers to experiment with (see Component choices, below).

The design

The design splits into two main functions: a current source which generates a voltage across a resistance, and an oscillator whose frequency can be varied by a voltage. Each of these functions can be provided in many different ways, and the method chosen depends on the details of the intended features.

The circuit diagram is shown in **figure 1**. As can be seen, the current source uses Q2 and its associated components. If we assume that the power supply voltage is exactly 5V, that the diode junction of D1 will have exactly the same voltage drop as the base junction of Q2, and that the ON resistance of Q1 is negligible, then we have a chance to estimate how the circuit will operate. If we further assume that the current gain of Q2 is exactly 100, and that the leakage current of Q1 when switched off is zero, then the calculations become relatively easy.

To find out how the circuit will perform, the first step is to discover how current is split between the base of Q2 and R1. If the transistor gain is 100, then 100 times more current flows through the emitter as flows in at the base junction. Therefore, the voltage across R2 alters 100 times more than it would for a given change in base current, if the base current alone were flowing through it. Therefore, the change in the base voltage is 100 times as much as you would expect for a load resistance of 47R. Therefore, so long as the transistor is operating in such a way that its gain remains around 100, the base of the transistor looks like a 4.7k resistor in series with a diode.

The effect of D1, R1, Q2, and R2 all together looks like 825R in series with a diode junction. If we subtract the diode junction from the power supply voltage (exactly 5V) then the remaining 4.35V will be split across two effective resistances in the normal manner for a potential divider.

If Q1 is switched off, then the only current through R1 and the base of Q2 is from R10. Across the whole potential divider there is 0.1906 millivolts per ohm of resistance, which gives 157mV across R1, and across R2. By Ohm's law, the current must be 3.34mA, which flows through LED1. (If it is flowing though an external load instead, then Q1 will be switched on.)

This calculation is approximate, because the gain of Q2 is not necessarily exactly 100, and because there may be a difference between the voltage across D1 diode junction and Q2 base-emitter junction. Because there is only a small voltage across R1, the difference in voltage drop could be a significant percentage of this voltage. However, at higher currents this error decreases in percentage terms, and the remaining error is due to the unknown transistor gain.

If Q1 is switched on, then the resistance in the lower part of the potential divider is now 956.5R, giving 2.44mV per ohm. Therefore the voltage across R2 is 2.01V, giving a current of 42.8mA. This is about the minimum current required to indicate

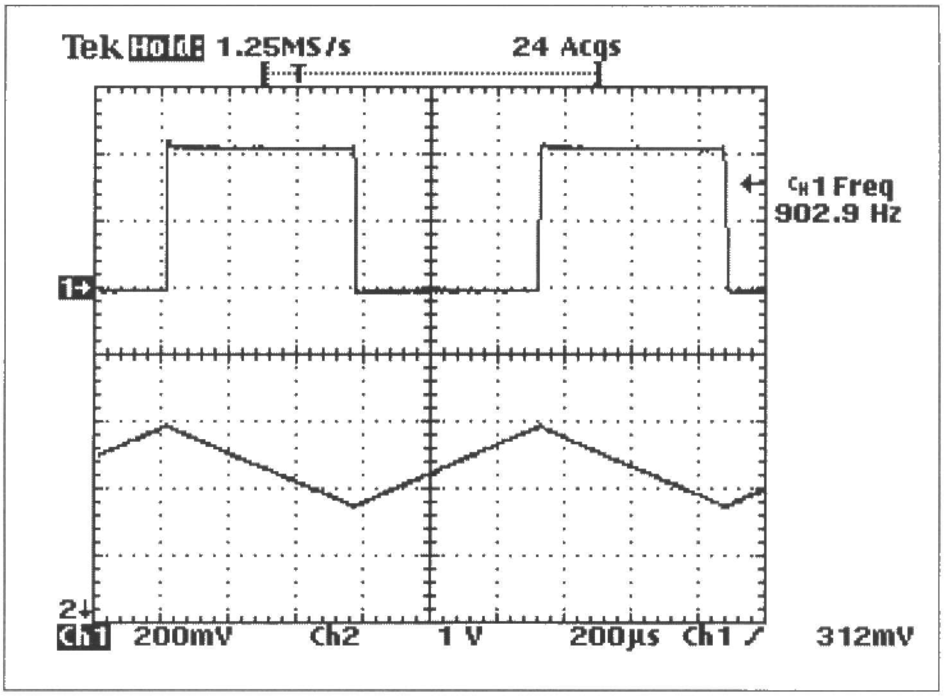


Figure 2: the oscillator waveforms, with a test resistance of 0.03R on the probe connections

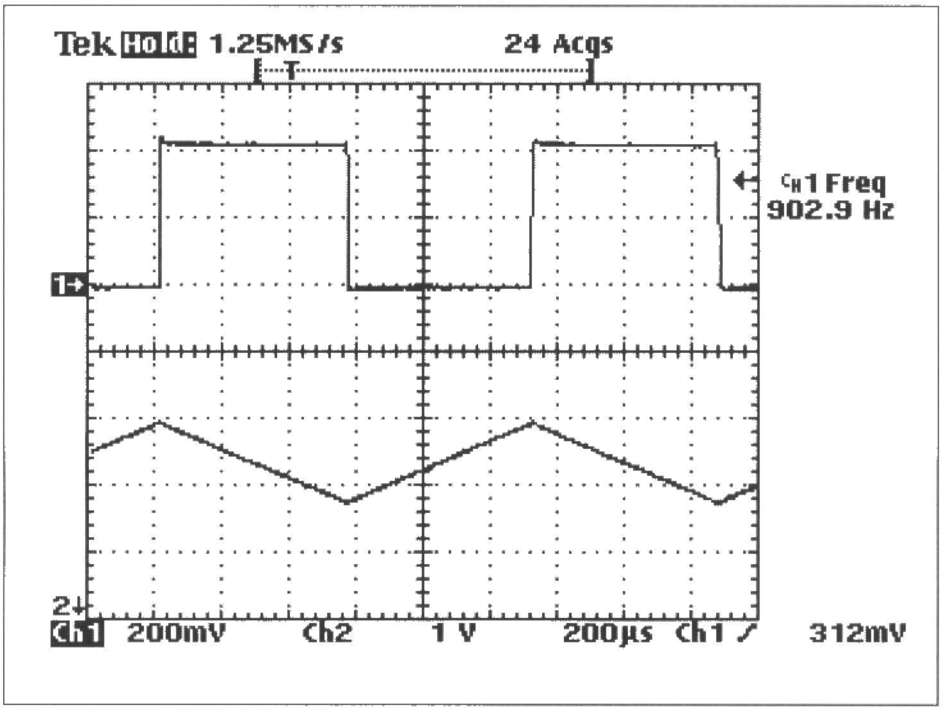


Figure 3: the output drive waveform

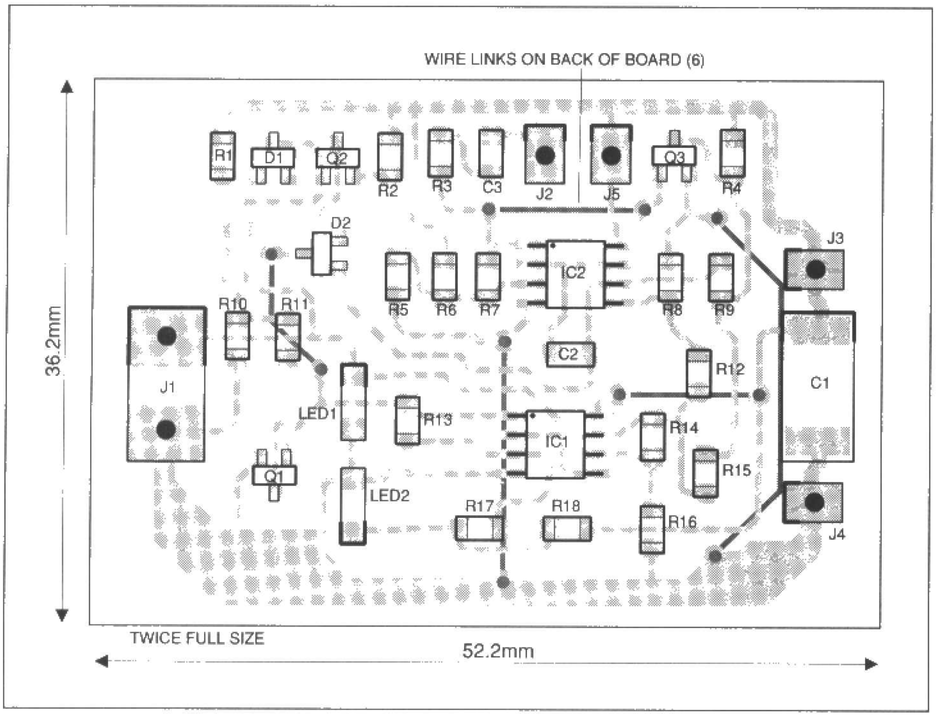


Figure 4: the component layout, shown considerably larger than life-size

the low resistances which this circuit is intended to be used with, unless very expensive ultra low offset op-amps were to be used.

The next part of the circuit uses IC1a as a comparator. This compares the voltage across LED2 with that across LED1, and switches on Q1 if the voltage across LED1 falls below that of LED2. In effect, LED2 is being used as a cheap and cheerful voltage reference, in a situation where anything more complicated is not justified.

A green led is used for LED1, and a red one for LED2. The voltage drop across a light emitting diode depends primarily on the energy gap over which the electrons are raised before they fall once again to emit a photon. Therefore the voltage drop for devices emitting higher energy photons is itself higher. Thus a green LED has a reliably higher voltage drop than a red one. In addition, leds typically work as fairly stable voltage references at low currents, so that a current too low to make LED2 easily visible can be used.

When the tester is in use tracing a short circuit, LED1 is extinguished. When it is not being used, LED1 is brightly lit as a power on indicator, whose current consumption is not needed when the circuit is in use and emitting sound. R13 and R17 provide hysteresis to prevent the comparator from switching Q1 on and off rapidly when the input voltages almost match, and the feedback to the input via Q1, Q2, and the (small) resistance of LED1 constitutes negative feedback.

The bleep

The voltage across LED1, which is also the probe voltage, is fed to IC1b connected as a dc amplifier with a gain of 22.36. Give or take any offsets on the input of IC1B, the output of this stage tracks the probe voltage from zero, but with enough gain so that the voltage drop across a 0.033R resistor was easily distinguishable from that across a 0.022R resistor (to quote an example used in testing).

At above 156mV in, the output of IC1 will reach its maximum (this may vary slightly from sample to sample of IC) of around 3.5V. Further increases of input voltage will not increase the output, but if the input switches the comparator circuit IC1a, then the bleep oscillator will be prevented from oscillating via D2. This simply stops the integrator from responding to its inputs.

The oscillator built using both parts of IC2 comprises an integrator and a comparator with substantial hysteresis. In order to permit the frequency to be controlled by an external voltage, the feedback from the comparator to the integrator is via a mosfet, supplied from the variable voltage. In order to place the feedback in the correct polarity, the comparator is connected as an inverting circuit, instead of the more familiar non-inverting comparator used in this type of oscillator.

IC2a is connected as a comparator, with fixed hysteresis. When the oscillator is working, the output from the integrator (IC1b) ramps between the switching levels of the comparator, as shown in the waveform diagram **figure 2**. What affects the frequency is the time taken to ramp between these two levels, which is itself determined by the voltage output from IC1b.

One reason for choosing this, rather than other varieties of voltage controlled oscillator, is that the output waveform from the comparator has approximately an even mark:space ratio. If a high impedance transducer is used, this can be driven directly, without an extra amplifier.

Figure 2 shows the waveform on the drain of Q3 at the top. This switches between 0V and 400mV, which is the voltage set by the presence of a 0.03R resistor across the probe connections. The lower waveform shows the output of the integrator, measured on pin 7 of IC2. The voltage excursion of this waveform is not set by the input voltage, but only be the hysteresis of the comparator.

The input of the integrator is alternately switched between ground and (via R15) the output voltage of IC1. The reference voltage of the integrator is set to half the output voltage of IC1 pin 7, so that the slope of the up ramp and the down ramp are almost equal, despite the fact that the input voltage is not switched symmetrically with respect to the power supply. In fact, because there is an extra resistance (R15) in series with the input when Q3 is switched off, the down ramp takes around 10 percent longer than the up ramp.

In order that some oscillation can take place even with a virtual short circuit on the probe input, R4 has been added to provide a small input signal to the integrator even when IC1 output is as close to 0V as it can get. On the prototype it was not possible to reduce the frequency of oscillation below an audible frequency even with a total short circuit.

The transducer drive waveform is shown in **figure 3** (the top waveform) with the integrator output shown for reference as the lower waveform. As can be seen, the op-amp output switches between approximately 0.6V and 3.8V, with transducer resonance adding ripples to the top and bottom of the signal. This drives the transducer well, and the fet switches cleanly, so all is well. R3 adds a small amount of damping in series with the output to protect the opamp in case a highly resonant device is connected. If the sound is too loud, its value can be increased to cut the level down to what is needed.

Straight to PCB

Partly because of publication deadlines, and partly due to the fiddly nature of making prototypes using surface mount components, this design, like last month's, was taken straight to pcb. The photographs show the first prototype. The wire link on the topside has been replaced by a track in the finished design. (The tracks have also been kept single-sided by using four wire links on the underside of the board.)

Originally the anode of D2 connected to IC2 pin 3, where it was to have reduced the hysteresis almost to zero when the output of IC1 a was low. This should have raised the oscillation frequency too high for audibility.

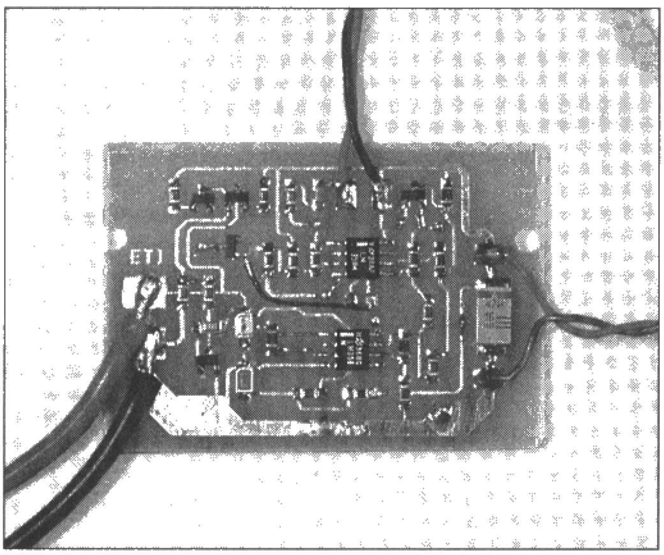
Unfortunately it did not raise it quite high enough. This was partly because the output of IC1a did not go to quite such a low voltage as I had expected, and partly because of delays in the oscillator loop.

A second look at that part of the design showed a way to stop the oscillator completely, and that is the design shown here. The unmodified prototype design functioned well, but the final design functions well without also emitting a constant whine, which I think is an improvement.

Assembly

The first thing to do is to fit the wire links to the back of the pcb, as shown in the darker tint in the component layout diagram of **figure 4**. The offboard wiring, in this case using the regulated power supply from Issue 13, is shown in **figure 5**. Make sure that the bent link is secure and in no danger of short-circuiting to anything else. Then the passive components and finally the semiconductors can be fitted. Don't forget that static can be more of a problem in the winter months, and take proper static precautions when fitting the semiconductors. In particular the mosfets are vulnerable, in that they have a very small gate capacitance, so that a relatively small amount of charge can break down the gate insulation.

Before fitting the LEDs, check their polarity carefully. On assembling the prototype I discovered that the red LED had the corner angled to mark the cathode, while the green LED had the corner angled to mark the anode! The batteries intended to power the project, in series with a 1k resistor, form a suitable source of current to test the polarity. When soldering the LEDs, be a little cautious because they can be more easily damaged by heat than some components.



The surface mount board made up and with the wires installed

If the tester is to be used with the power supply project from last month, then the power supply resistors should be chosen from the table in last month's article to set the power supply output voltage to 5V.

When the pcb has been assembled, connect the piezoelectric transducer and the power supply board, and apply the power. The green LED should light fairly brightly, and the red one should light faintly. If either does not light, measure the voltage across it and make sure that it does not exceed a normal LED forward voltage. If it does, then the LED may be fitted the wrong way round.

Then connect a diode across the probe connections on the pcb. One way round, the diode will conduct, and there should be a high pitched sound from the transducer. The green LED will extinguish.

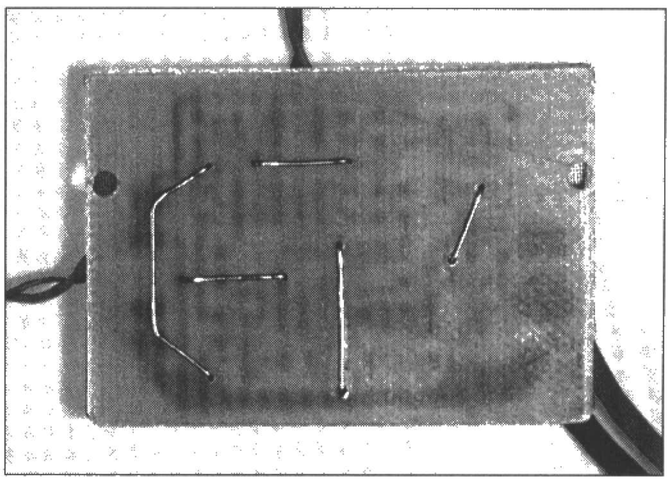
The prototype used probes from Farnell Electronic Components. These probes are very good for the purpose, and have removable shields to prevent the probes themselves from causing short circuits in cramped surroundings. However, some constructors may not find it economic to purchase probes, 4mm plugs, and 5M reels of flexible wire just to make up two short test leads. An alternative would be to purchase a set of replacement multimeter leads such as Cirkit stock number 56-00601, and cut them to length, using the probe part and discarding the plug.

In either case, the wire to the probe should not be too long, as it will add resistance to the circuit and reduce its effectiveness. About 1 foot of total length on the prototype worked well. The probe wires should be soldered to the connection pads on the pcb to minimise the resistance of the connection.

It would have been possible to design the unit to use two wires to each probe to sense the voltage at the probe itself, but this would reduce the flexibility of the connection to the probe and was deemed unnecessary, since long leads are not helpful for this sort of test equipment.

The main pcb was fitted to the case using two screws in to the two mounting points closest to the front, while the power supply board was secured using double sided adhesive tape. A hole was drilled to allow the green LED to be seen, and it is a good idea to fix a transparent window inside the case if any transparent plastic is available.

The photograph shows the internal wiring including the switch, and much of the wiring is shown in the picture of the boards connected together before final assembly.



The wire links on the rear of the board. The board is single-sided, and the links solder to pads on the topside of the board

PARTS LIST *for the 'Short Cut' Continuity Tester*

Resistors

All 0805 5 percent unless otherwise stated

R1, R11	1k (eg Electromail 137-203 or Farnell 613-095)
R2	47R (eg Electromail 137-045 or Farnell 612-935)
R3	100R (eg Electromail 137-089 or Farnell 612-972)
R4, R13, R14	470k (eg Electromail 137-528 or Farnell 613-411)
R5, R6, R7, R8, R9, R10, R12, R16, R17, R18	22k (eg Electromail 137-360 or Farnell 613-253)
R15	2.2k (eg Electromail 137-247 or Farnell 613-137)

Capacitors

C1	47u 6.3V or 10V or 16V D-case tantalum (eg Electromail 262-4557 or Farnell 498-762)
C2	4.7nF 0805 X7R ceramic capacitor (eg Electromail 264-4365 or Farnell 499-213)
C3	100nF 0805 X7R ceramic capacitor (eg Electromail 264-4416 or Farnell 499-687)

Semiconductors

IC1, IC2	LM358M dual op-amp (eg Electromail 856-724 or Farnell 399-565)
Q1, Q3	BS170F n-channel mosfet (eg Electromail 641-932 or Farnell 932-840)
Q3	BC857B npn transistor (eg Electromail 288-581 or Farnell 506-229)
D1, D2	BAS16 diode (eg Electromail 287-235 or Farnell 646-544)
LED1	Red smd led (eg Electromail 247-1000)
LED2	Green smd led (eg Electromail 247-0984)

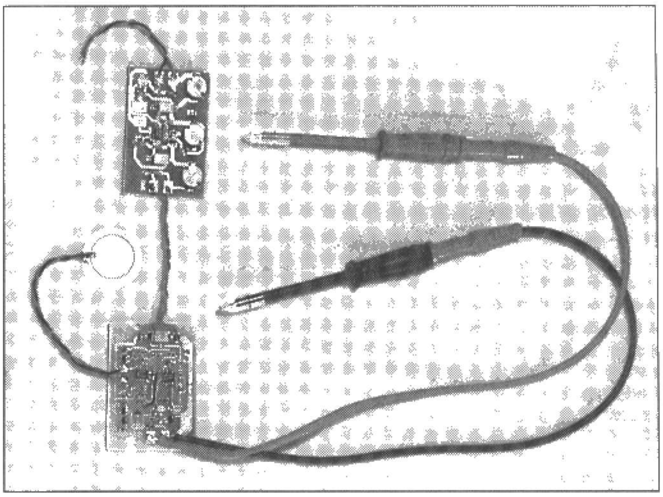
Miscellaneous

Piezoelectric transducer (see text)
Probes (eg Farnell 523-665 red and 523-677 black)
4mm plugs to connect to probes (if the suggested ones are used)
Extra flexible low-resistance wire (eg Electromail 225-6176 red or 225-6182 black)
Switch: small on-off switch to suit case
Power supply project from last month's ETI, set to 5V
Battery holder for 2 AAA cells

Case (eg Farnell 462-172)

Note: some of these components are only sold in multiples - for example, resistors are sold in multiples of 50.

Farnell Electronic Components, Canal Road, Leeds LS12 2TU Tel 0113 2636311.
Electromail, PO Box 33, Corby, Northants NN17 9EL. Tel 01536 405555.



The board wired up to last month's regulated power supply, and with the probes added. Other power supplies can be used (see text)

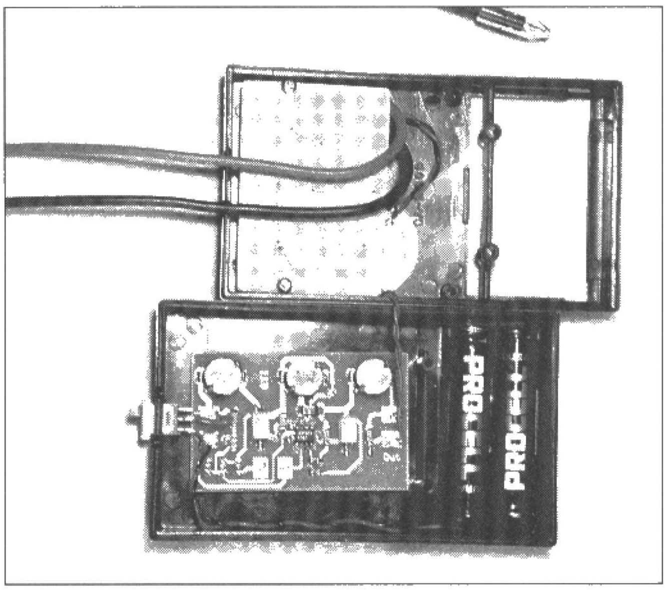
Component choices

The output transducer chosen was picked on the basis that it was loud enough, and would fit to the inside of the chosen case without the need to drill any holes. The one chosen consists of a thin circular plate with a round ceramic element attached, for example Electromail 228-1605 (similar items are also to be found in the Cirkit catalogue).

If a louder sound is needed, a small transducer in a plastic housing could be used, such as Electromail 172-7289. This will almost certainly give a much louder sound, but it has not actually been tested with this project. Several similar transducers to hand all gave louder sound output than the one actually chosen.

To gain an audible response to even lower resistances, one can increase the current, and increase the gain of the dc amplifier. The dc amplifier will also amplify its own input offsets, so this approach is limited in it application. Equally, increasing the current can only be carried out as far as will not damage components due to excessive power dissipation.

The maximum safe value of current using the size of components specified is approximately 75mA. To get close to this, R1 should be reduced to 680R, and R2 reduced to 22R. If still more current is required, R2 must be replaced by a higher wattage component, and this exercise is left to any readers who may wish it.



The continuity tester (left) and power supply (right) boards mounted into a case with batteries and a single on/off switch. If other types of batteries or power supply are used, chose a different case to suit

In use

The project is effective as an ordinary continuity tester, a short circuit locator, and a diode tester. It will even test red LEDs, although it puts a current of 50mA through them, so prolonged testing of low current LEDs might damage them.

The flat ceramic transducer glued to the inside of the case gave sufficient sound level in a quiet environment, but if it is intended to use the tester in a noisy place, one of the louder alternatives should be used.

The current consumption was 17mA on standby using a pair of new AAA cells. This rose to 41mA at the minimum voltage at which the prototype worked correctly, 1.5V. The corresponding operating currents (short circuit on the probes) were 102mA and 250mA

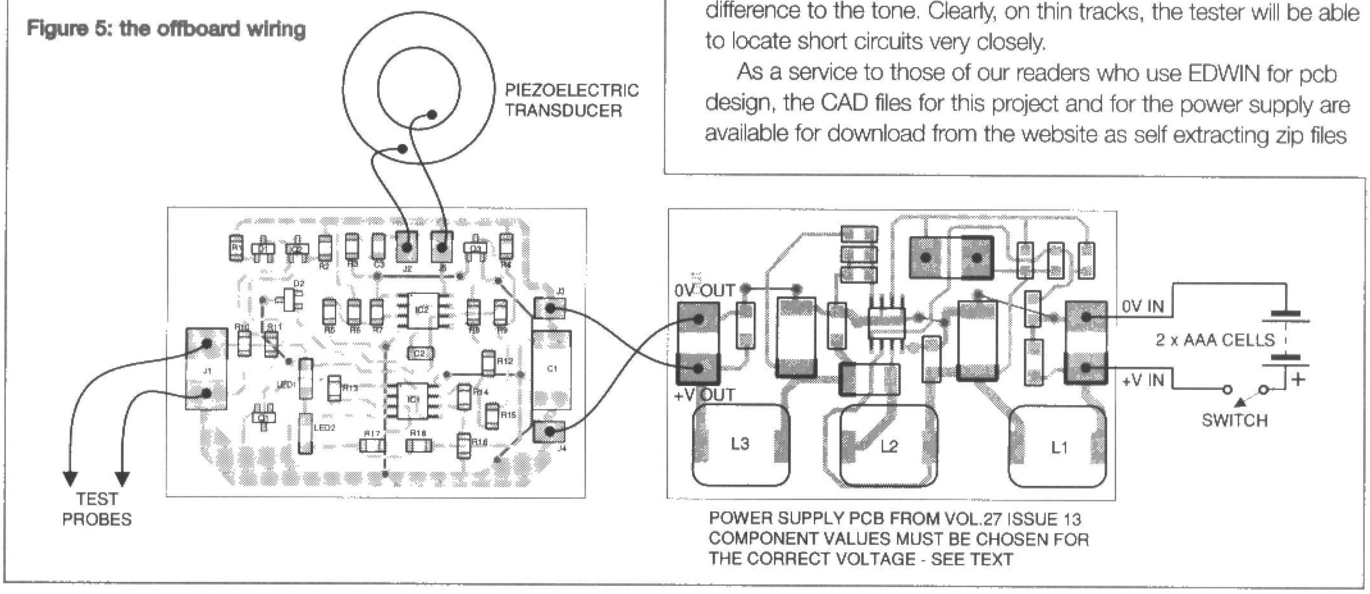
The capacity of alkaline AAA cells is approximately 1.1Ah, which suggests that the battery life will be approximately 41h on standby. A reasonable operating cycle would probably more than halve this, but still the batteries will not require to be changed too frequently.

The output from the current source was measured as 45mA, compared with the approximately 43mA calculated using several approximations. This performance is reasonable, and it illustrates the point that a lot can be learned about a circuit in advance using approximate calculations as a starting point.

The short circuit tracing capability worked in tests, with a difference of 5mm on 0.012 inch width track making an audible difference to the tone. Clearly, on thin tracks, the tester will be able to locate short circuits very closely.

As a service to those of our readers who use EDWIN for pcb design, the CAD files for this project and for the power supply are available for download from the website as self extracting zip files

Figure 5: the offboard wiring



A Radio Frequency Probe

Raymond Haigh

Although designed to complement the wobbulator described in a recent issue of ETI, this simple probe unit can be used with a sensitive meter for tracing low RF voltages with a minimum of disturbance to the circuit under test.

When the wobbulator described in last month's issue (ETI Vol 27 Issue 13) is used to optimise the alignment of a radio receiver, the output from the receiver's detector is connected to the 'Y' input of an oscilloscope in order to produce a visual display of the IF response. The oscilloscope is, of course, plotting the way the DC voltage produced by the detector changes in magnitude as the injected signal sweeps across the IF passband. In order, therefore, for the wobbulator and oscilloscope combination to function, the RF voltage has to be detected, or rectified. It also has to be sufficiently large to overcome inefficiencies in the detector and create a display on the oscilloscope screen.

Complex receivers often incorporate more than one stage of frequency conversion, with front-end IF filters working at a higher frequency to reduce image responses. These filters are isolated from the receiver's detector circuits, and signal levels are low. In order, therefore, to display a response curve, their output needs to be amplified and then rectified. This has to be done without imposing any significant additional loading, as this would affect the frequency response of the filter.

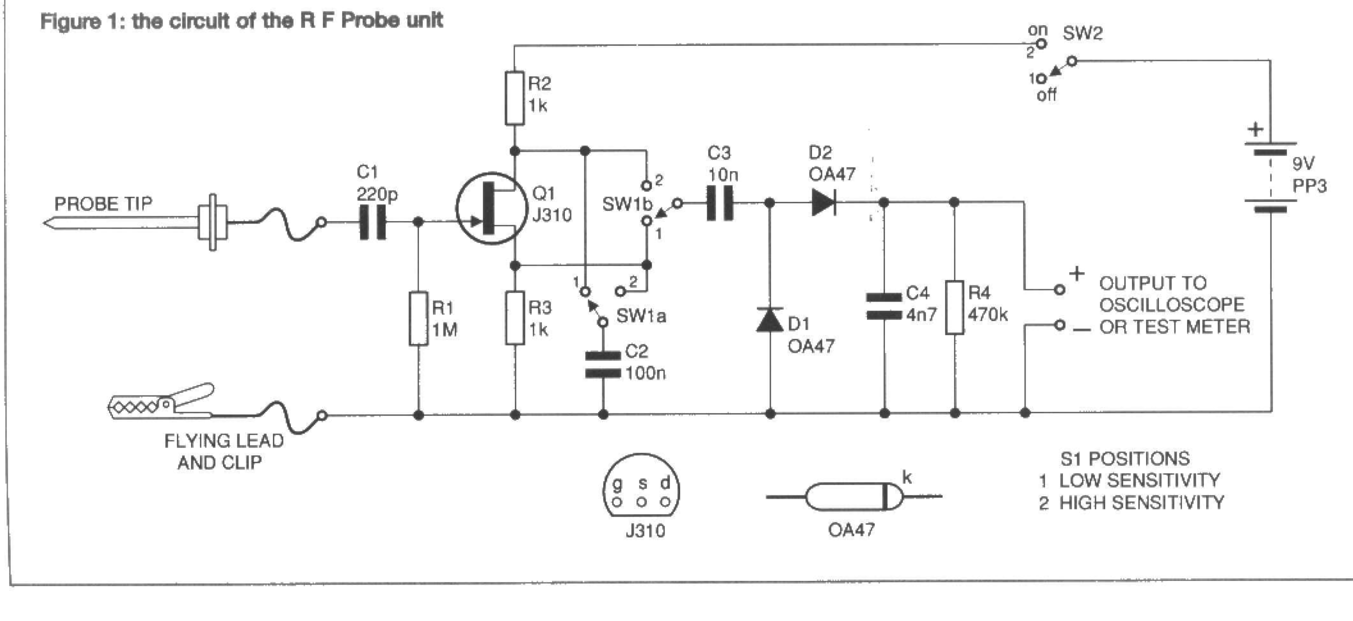
This probe unit amplifies the RF voltage at the filter output, and rectifies it so that it can be connected to the 'Y' input of the oscilloscope. It has a high-input impedance in order to minimise disturbance to the circuit under test. Although designed for use with the wobbulator, it can be used with any test meter or microammeter to trace and compare the magnitude of low RF voltages.

Diode rectifiers

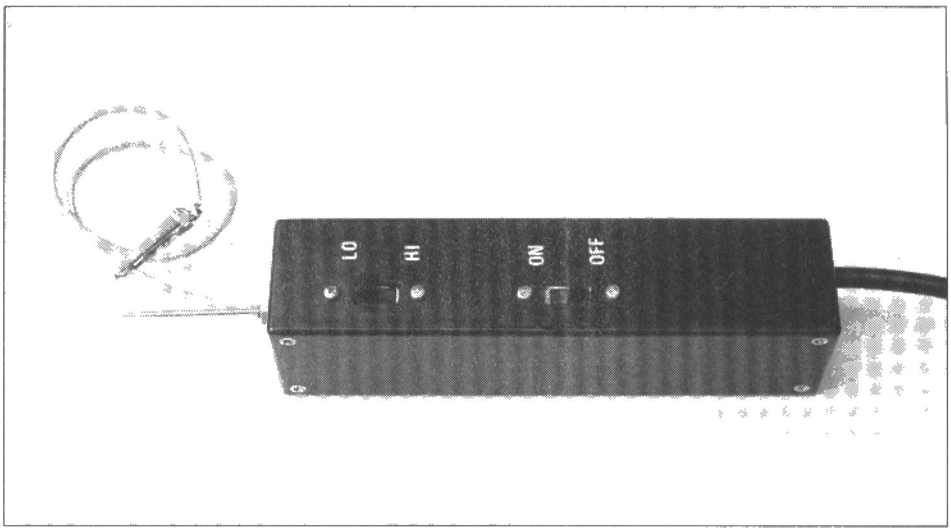
The semiconductor diodes used almost universally as rectifiers and as detectors in AM radio receivers are imperfect devices. Their greatest flaw, when used as signal detectors, is their insensitivity to small voltages. The threshold at which forward conduction really starts is about 0.2V for germanium and 0.6V for silicon diodes. Above these break points, current flow increases until, at around 0.5V for germanium and 0.8V for silicon, forward current is rising steeply. The forward conduction threshold for Schottky (or hot-carrier) diodes is similar to germanium, and is usually around 0.3V.

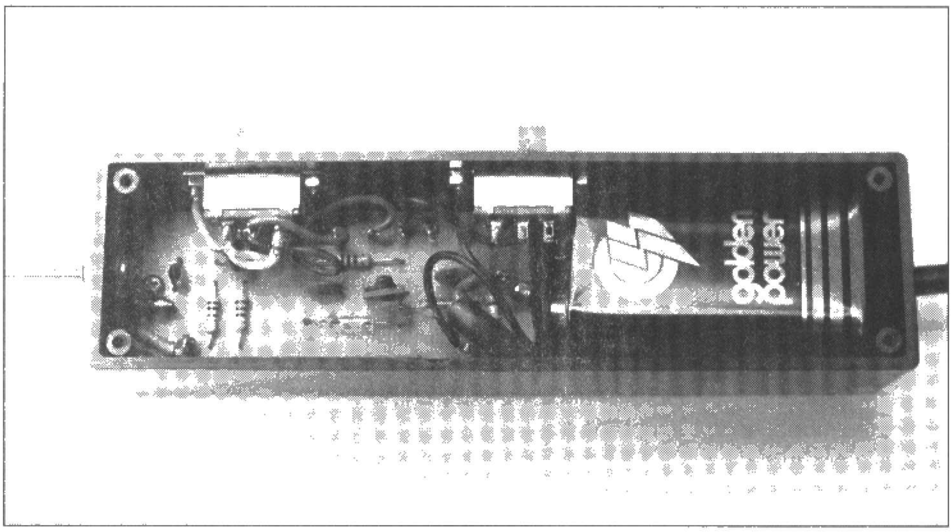
Germanium diodes will, therefore, become increasingly inefficient as the input falls below 0.2V, and their response will not be completely linear until the applied voltage is in the region of 0.5V. With silicon diodes, the situation is worse.

Figure 1: the circuit of the R F Probe unit



Even when circuit impedances are low enough to tolerate the direct connection of a semiconductor diode, RF voltages very much below 0.2V will not register on the meter or oscilloscope. In order to make the probe more sensitive, the RF voltage must be amplified before it reaches the diode. With an appropriate choice of active device, the amplifier can also serve as a high to low impedance buffer stage, minimising disturbance to the circuit under test. This is the basis of the probe design described here.





The circuit

The circuit of the probe unit is given in **figure 1**. The DC blocking capacitor C1 connects the RF input from the probe tip to the base of fet Q1. The high input impedance of this stage (1 megohm shunted by a few pF) limits loading on the test circuit. R1 ensures correct biasing of the fet, which can be connected in either the common drain or the common source mode.

When the common source configuration is selected, an amplified signal voltage is developed across the drain load resistor R2, and the source bias resistor R3 is bypassed at RF by C2.

When the common drain, or source follower, arrangement is adopted, a slightly attenuated signal is developed across R3, which now functions as a source load resistor, bypass capacitor C2 being connected to the drain.

In this way, the transistor can be made to amplify the signal, or process it with a small amount of attenuation (the gain of a source-follower is slightly less than unity). SW1 selects the mode of operation by changing over the connections to the bypass capacitor and the diode coupling capacitor.

The output from the high-impedance buffer stage is coupled, via C3, to germanium diodes D1 and D2 arranged in a voltage doubling circuit in order to maximise the sensitivity of the probe. On the negative going cycle, current flowing through D1 charges coupling capacitor C3. When the cycle swings positive, this charge is added to the current flowing through D2, and the output voltage is, in theory, doubled.

C4 bypasses residual RF, and R4 is included to provide a DC current path for the diode network. The input impedance of some oscilloscopes and test meters can be very high, and the value of R4 was determined empirically in order to maximise the output from the probe under these conditions.

Current drain is a very modest 1.5mA, and the unit is powered by a PP3 battery which can be accommodated in the probe case. SW2 functions as an on/off switch.

Components

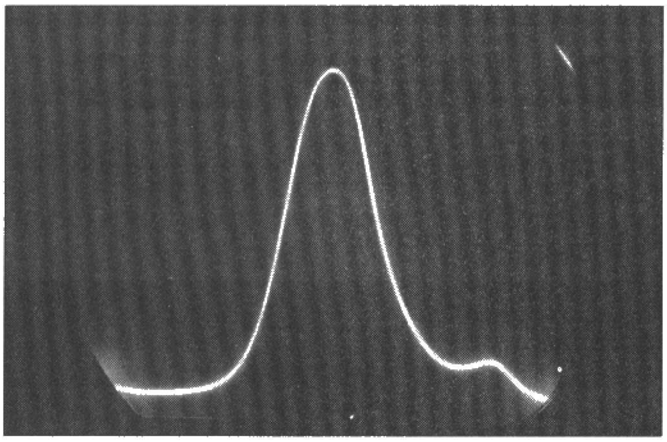
The ubiquitous 2N3819 can be used in place of the J310 FET, but the probe will be less sensitive. Any germanium or Schottky signal diodes should prove suitable. If the probe is to be used in conjunction with a moving coil meter, the specified OA47 diodes will give the highest readings from very low signal inputs. When the probe is connected to an oscilloscope or high impedance electronic test meter, little or no difference can be discerned between the various types of Schottky and germanium signal diodes. The probe will still function if silicon diodes are substituted, but there will be a very marked deterioration in low-signal sensitivity.

Construction

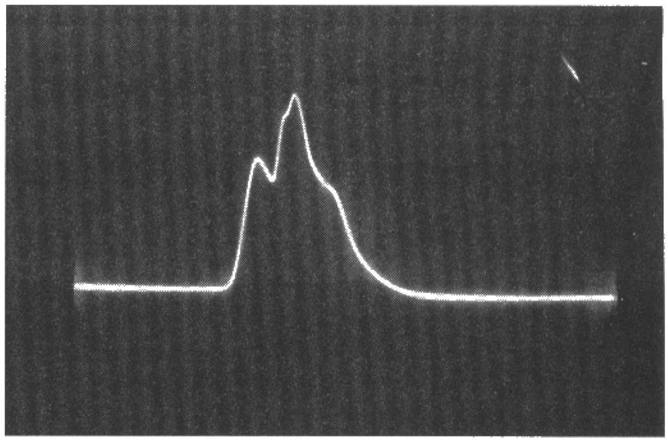
All of the components, with the exception of the switches and probe tip, are mounted on a small PCB. Details of the component side of the board and the connections to the switches are given in **figure 2**. Vero pins, inserted at the lead-out points, will simplify the wiring to the switches, probe and battery connector.

A Stanley knife can be used to form the rectangular holes in the side of the case for the switches, and it is a good idea to define the corners of the holes with a 1mm drill before attempting to cut them out.

The probe tip is formed by drilling a hole through a short 4BA bolt and soldering a blunted darning needle into it. The bolt, and a solder tag, are secured in the end of the case.



The trace produced by an inexpensive 4 kHz mechanical filter and its matching transformers, with the probe gain set high and used with the wobbulator described last month. (Compare with photograph on page 56 of last month's ETI showing the response of the filter and the subsequent IF strip).



The trace produced by a 2.6 kHz ceramic filter and its matching transformers with the probe gain set high and probe used with the wobbulator. The comparisons suggested confirm the linearity of the probe when its gain is set high and also reveal the way in which the shape of the IF passband is largely determined by any filter elements.

Initial testing

Check the orientation of semiconductors on the PCB, and check for bridged tracks and poor soldered joints. Connect a fresh PP3 battery. Current consumption should be approximately 1.5mA.

Connect the probe output leads to a test meter set to a low voltage range (0-5 or 0-10V). Switch probe gain to low and apply the probe tip to the low impedance output of the wobbulator described in last month's ETI (or to some other RF signal generator). With the wobbulator switched to Range 2 and its output set at maximum, the meter reading should be in the region of 1.5V. (Voltage doubling is taking place within the probe, so this is not the true RMS output of the wobbulator). Turn down the wobbulator or signal generator output until the meter reads around 0.1V, and switch probe gain to high. The meter should now read approximately 1V, confirming that the probe amplifier is functioning.

Performance

A comparison of oscilloscope traces produced via the probe and by direct connection to the receiver, (see the figures and photographs) confirms that the response of the unit is acceptably linear and there is no noticeable disturbance of the circuit under test. Moreover, the probe is sensitive enough to produce good traces from the low-level signals encountered at the front-end of receiver IF strips.

The probe can be used with a test meter, (or any moving coil meter with an FSD of 100uA or less) to trace and compare the magnitude of RF signals. The probe is marginally more sensitive when connected to a high impedance digital or analogue electronic voltmeter. With this combination, signals well below 10mV can be clearly displayed. The unit is, therefore, extremely useful for detecting the presence of weak RF signals and for checking that circuitry has been optimised to maximise them.

Measuring the precise value of low RF voltages is a more difficult matter, however. Reducing diode efficiencies inevitably cause probe output to fall at a faster rate than the applied voltage for inputs below 40mV or so when the unit is switched for high gain.

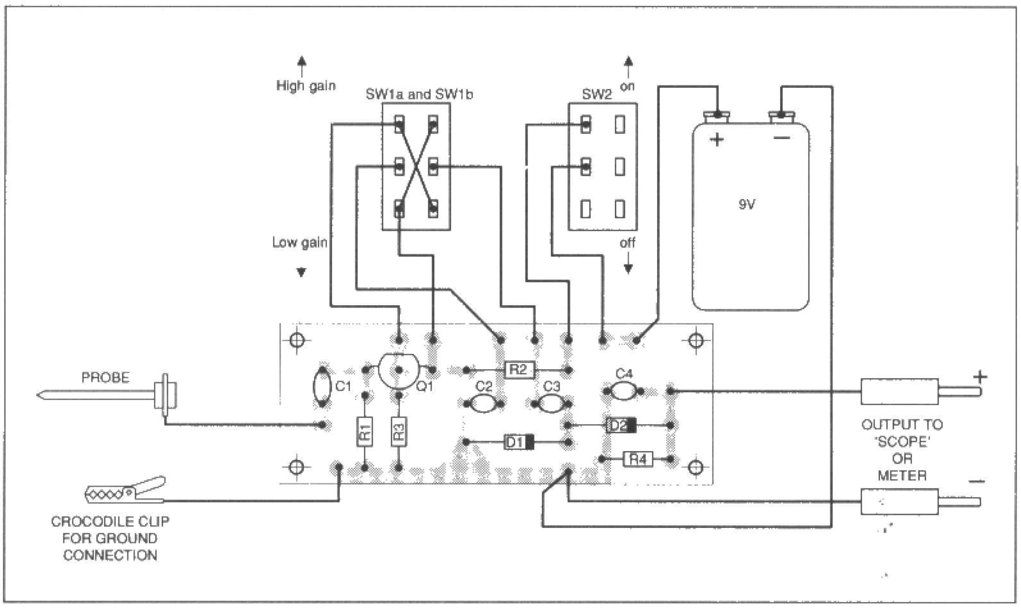


Figure 2: the component layout of the RF probe

Nevertheless, between this level and around 350mV, when overloading begins in the high gain mode, the output of the prototype is approximately 18 times the RMS input voltage.

When the probe is switched for low gain, there is no amplification of the RF voltage before it reaches the diode rectifiers, and the point where output begins to fall at a faster rate than input occurs at around 250mV. Between this level and about 1.5V, the onset of overload with the probe in the low gain mode, output is approximately twice the RMS input voltage.

The above checks were made with the prototype probe connected to a high impedance voltmeter. If the unit is to be used to measure voltages with some precision, individual probe and meter combinations should be calibrated against a known RF voltage.

Frequency response of the probe is reasonably flat, but begins to tail off gradually above 40MHz or so.

Using the probe with the Wobbulator

Connect the probe output leads to the 'Y' input and ground terminal of the oscilloscope. Connect the flying input lead to the ground plane of the receiver. Apply the probe tip to various points along the signal path through the IF amplifier, adjusting probe and, if necessary, 'Y' input sensitivity, to produce a display on the screen. When working from the first (or only) mixer towards the detector stage, reduce signal injection levels, as necessary, to avoid overloading the probe and/or the receiver. Overloading manifests itself as a flattening of the oscilloscope trace (wobbulator builders can compare the trace photographs on page 56 of last month's ETI).

Output from the probe is positive going, and the response curve is displayed as a peak (rather than a trough) on the screen.

PARTS LIST for the RF Probe

Resistors
0.25 W, 5 percent tolerance or better.

R1	1M
R2	1k
R3	1k
R4	470k

Capacitors
All ceramic, 25V working or greater.

C1	220pF
C2	100nF
C3	10nF
C4	4n7

Semiconductors

Q1	J310, field effect transistor.
D1	0A47 germanium signal diode.
D2	0A47

Miscellaneous

SW1	2 pole, 2 way, miniature slide switch.
SW2	2 pole, 2 way, slide switch, (one pole not used).

Probe tip (see text), small crocodile clip, battery connector, grommet for output leads, output leads and banana plugs. 8BA nuts and bolts for securing switches. PCB materials, Vero pins and hook-up wire.

Plastic case. Maplin retail a 120 x 30 x 25mm box, part number FT31J. A more expensive case, which comes complete with a probe tip, is Maplin part number JX57M.

The diodes and the J310 fet can be obtained from Cirkit Distribution, Park Lane, Broxbourne, Herts. EN10 7NQ (Tel 01992 441306).

PIC Barcode Reader Interface

Decode barcodes using a low cost barcode reader wand and a PIC interface to a PC.

Roger Thomas

The full PIC assembler source code, interface circuit and PC program details are included here. A Windows 95 program is available to decode and display the barcode.

Industry makes extensive use of barcodes to identify items, and there are many different types of barcode. For this project I have concentrated on the EAN-13 numbering system, which encompasses the majority of barcodes that we see on goods.

'EAN' derives from the name of the original numbering organisation, European Article Numbering Association, and the '13' is the thirteen digit version of this international system. The EAN-13 barcode system is an industry standard for product identification, used throughout Europe and most other countries, except North America. In the USA and Canada a similar coding system known as Universal Product Code is used, adopted as an industry standard in 1973.

The Article Number Association (ANA) is a member of the EAN International organisation and was established in 1976. It is the UK authority for issuing company prefix numbers. The UK country prefix is 50. The country prefix is the first two or three digits of the barcode number.

Any UK organisation that needs an EAN number has to become a member of the ANA and is allocated a five-digit company identity number. The company then allocates a different number to each product, usually sequentially. EAN numbering organisations in other countries allocate company identity numbers that vary between four and six digits.

Contrary to what some people think, the prefix number does not necessarily indicate where the item was manufactured, only which EAN numbering organisation allocated the company prefix. A product manufactured in another country but sold by a UK company may well have a UK barcode number.

EAN country prefix codes for European countries.

France	30 to 37
Belgium and Luxembourg	54
Denmark	57
Finland	64
Norway	70
Sweden	73
Switzerland	76
Italy	80 to 83
Spain	84
Netherlands	87
Austria	90,91
Bulgaria	380
Slovenia	383
Croatia	385
Bosnia-Herzegovina	387
Germany	400 to 440
Russian Federation	460 to 469
Estonia	474
Latvia	475
Lithuania	477
Ukraine	482
Moldova	484
Armenia	485
Georgia	486
Kazahkstan	487
Greece	520
Cyprus	529
Macedonia	531
Malta	535
Ireland	539
Portugal	560
Poland	590
Romania	594
Hungary	599
Slovakia	858
Czech Republic	859
Yugoslavia	860
Turkey	869

(From information provided by the ANA)

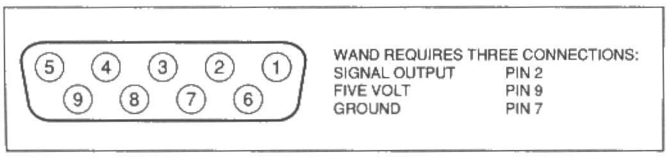


Figure 1: wand 9 pin 'D' connector (male), viewed from solder side

The use of the barcode numbers has two primary advantages for the retailer: first, it allows the retailer to identify and track products relatively easily. The same product may have a different product code as it moves from multiple packs in the warehouse to individual units in the store. Secondly, it gives a product description on the till receipt as well as the price, and this sales information can also be used by the retailer for stock control. Supermarkets have accurate information (in real time)

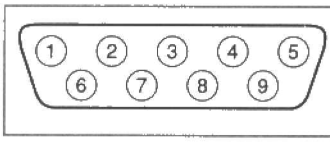


Figure 2: RS232 9-pin D connector (female) viewed from solder side

about what is selling, and can estimate future sales, stock levels and replacement orders - all from a few stripes printed on the package.

In general, barcodes do not include the price or product description: these are obtained from the computer system that the checkout or barcode scanner is connected to. However, some perishable products (cheese and fish, for example) that are sold by weight and require an individual label sometimes have the price encoded in the barcode. You may notice that barcodes used on own-label store items have a shorter barcode. As these barcodes are used only within the one trading organisation, they are not part of the EAN-13 numbering scheme.

Other barcodes numbers used to identify books and magazines are also part of the EAN-13 scheme. These may look different because they are generally printed smaller and may have an additional barcode. The smaller size does increase the chance of a mis-read.

The International Standard Book Number (ISBN) is the unique ten-digit number allocated to every book via its publisher. The ISBN system had already been in use for a long time internationally before the EAN-13 system was adopted. ISBN is represented in the EAN-13 coding scheme with the first three digits allocated as 978. The final digit is the EAN calculated check digit and not the original ISBN check digit. It is possible that the original ISBN number will also be printed near the EAN-13 barcode.

A similar system is used to identify publications that are part of a series - called the International Standard Serial Number (ISSN). Serial publications such as newspapers and magazines are part of the scheme, as are audio books and CD-roms designed for education, but not music CDs or music cassettes.

The ISSN coding scheme starts with the first three digits being 977, followed by the ISSN number of the periodical, ending with the check digit. ISSN codes can also have a separate two- or five-digit extension code. Depending on whether the publication is weekly or monthly, the two digits can indicate the week or month of the year. Five-digit extension can include the price. The five-digit option will start with a '9' if it is used in-house.

UPC

The Universal Product Code (UPC) is an eleven-digit code (plus check digit), allocated by the American Uniform Code Council (UCC). A 'number system' digit precedes the product number: for example, 0 for the retail version, 2 for items weighed at the store, 3 for drugs and health related products, and so on. Unlike EAN-13, the UPC number has a fixed six-digit length company prefix field and a fixed five-digit length item field (giving 1,000,000 companies with the ability to number 100,000 different items).

In most respects, the EAN-13 can be regarded as a superset of the UPC code. Consequently an EAN-13 scanner can decode the UPC number simply by preceding the number with a zero. Some UPC barcode systems cannot decode the longer EAN barcode. Many American retail databases cannot, at present, handle the 13-digit numbers or the variable length information encoded within the barcode number.

However, North America users will be required to scan EAN-13 barcodes as the current UPC numbers are expected to exhausted by the year 2005, after which the UPC will adopt the EAN-13 system. The UCC recently acquired country prefixes 10, 11, 12 and 13 from the EAN International organisation in preparation for this change. By this means, a truly global product identification system will have been created.

The barcode reader

A barcode wand looks very much like a large pen with a metal barrel. Low cost wands are widely available for between £40 and £60 from suppliers like RS/Electromail. In operation they rely on the user moving the wand over the barcode. Most wands convert the optical return signal seen at the tip into a digital signal that is then fed (via the attached cable) to the computer for decoding. More expensive wands have a built in microprocessor that can decode the barcodes directly.

Barcodes do not have to be printed in black on white, but the wand must be able to distinguish between the bars and the background. To do this, the wand illuminates the barcode with a beam of red light. The printed bar should absorb the light while the background reflects the light back to the wand detector. The detector only responds to the change of intensity, not to the colours used. Reds (which reflects the red, of course), yellows, and white are suitable background colours; they reflect the light. Blue and green (provided they are not too pale) and black can be used for the bar - they are dark and absorb the red light from the wand. A common misconception is that the red is a dark (absorbing) colour, so cannot be used as a background colour. Red gives a dark output on monochrome photocopiers, which use blue-white illumination for scanning. That is absorbed by red. The red illumination used by the barcode scanner is reflected by red, so that it can be used as a background colour. If you drink a certain brand of tea you can verify this.

Underneath the barcode is printed the actual number. If a barcode does not scan correctly, the operator can manually enter the number. The check digit is very useful as it prevents a valid barcode number being entered with some digits accidentally transposed.

A blank area (sometimes referred to as the 'quiet zone') appears before and after the barcode. The barcode wand uses this zone to determine the exact beginning and end of the barcode. The barcode standards require a quiet zone to be around quarter of an inch in width, or a minimum of ten times the width of the smallest element.

EAN-13 uses proportional coding for the barcode using four different widths, which is more space-efficient than binary coding. There are no inter-character gaps with EAN-13. All spaces are part of the individual character. In addition to the 13 characters, there are two guard characters and a centre character. These characters may be extended below the barcode.

If you look at a barcode, the 5 (first number in the UK country prefix) is shown on the left before the guide bars, not encoded in the barcode. This is because, in the UK, this number is assumed automatically. This does not mean that the same barcode from a different country will scan, since the check digit incorporates the full barcode number, including the '5' prefix.

The barcode pattern is taken from three different tables (A, B and C). The first six characters are taken from Table A

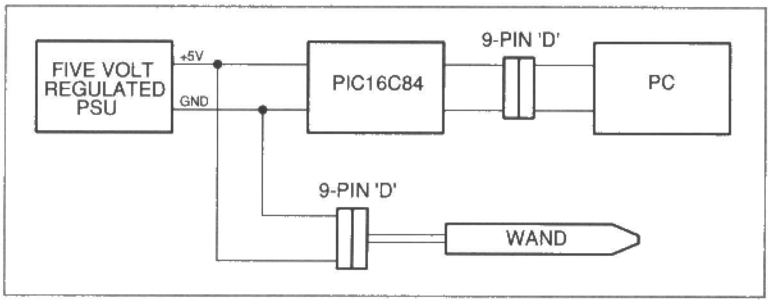


Figure 3: connections between the barcode want, power supply and Pic/PC

or Table B depending on their position, first number taken from Table A, second number from Table B, and so on. Foreign barcodes do not always follow the same sequence. This does not cause a problem when decoding, as the two tables are distinct and do not have any duplicate patterns. The last six digits (product number) are taken from table C.

Table A (left)	Table B (left)	Table C (right)
0 = 0001101	0 = 0100111	0 = 1110010
1 = 0011001	1 = 0110011	1 = 1100110
2 = 0010011	2 = 0011011	2 = 1101100
3 = 0111101	3 = 0100001	3 = 1000010
4 = 0100011	4 = 0011101	4 = 1011100
5 = 0110001	5 = 0111001	5 = 1001110
6 = 0101111	6 = 0000101	6 = 1010000
7 = 0111011	7 = 0010001	7 = 1000100
8 = 0110111	8 = 0001001	8 = 1001000
9 = 0001011	9 = 0010111	9 = 1110100

EAN-13 barcodes do not have any error correcting capability only error detection provided by the check digit. Misreads are rare as the number of possible characters that can be encoded in EAN-13 is very high compared to the number that is used. There are a possible 128 combinations but only 30 are actually used (three different tables, each coding ten digits). In general the barcode either scans correctly or is rejected, prompting another read.

As can be seen from the tables, the maximum black or space width is 4 and there are always two bars and two spaces per number. Overall, there is virtually an equal number of ones and zeros. If you are trying to visually decipher a barcode, it is easier to attempt to decode the last six numbers as the pattern comes from the same table (Table C). If it is difficult to decode, this is hardly surprising as it is intended for machine reading. The number is printed underneath for human inspection.

Barcode wand connections

The wand is connected to a 16C84 PIC, which converts the serial signal from the wand into various widths, and transmits this via a serial connection to the computer. It is not possible to power the wand and the PIC from the RS232 control lines, as the wand requires about 40mA continuous current, which is in excess of what can be safely supplied. Consequently, an external five-volt power supply will be required to power the wand, in which case it is sensible to power the PIC circuit from the same supply. This will also prevent problems associated with differing voltage levels caused by the use of two separate power supplies.

To connect the PIC interface to the wand and power supply requires a 'Y' cable. The actual construction of the wiring will depend on the type of wand connector and whether the serial connection is via a 9- or 25-pin D connector.

Wands usually require three connections: +5 volts, ground and signal output. The ground is connected to the metal barrel of the wand, so a simple resistance test between the barrel and pin will confirm which one should be connected to ground.

Assuming 9-pin serial and 9-pin wand connector, the connection is as shown in **figure 1** and **figure 2**.

The serial data cable should be kept reasonably short as the transmission speed is relatively fast at 57,600 baud. The PIC interface circuit consists of a PIC 16C84, a 4-MHz crystal, two 33pF capacitors, power supply decoupling capacitors (as appropriate) and two resistors. The program should run correctly on most PIC microcontrollers, but it has only been tested on the 16C84 and 16C620. A clock frequency of 4MHz is needed for the ASM barcode to work correctly. The connection diagram and circuit diagram are shown in **figure 3** and **figure 4**.

That is quite a short circuit: indeed, one of the resistors may not be needed. Barcode wands either have an open collector output where a pullup resistor is usually required, or a ttl output, in which case the resistor may not be needed. The other resistor is used on the serial RS232 data line.

As the circuit is so small, I have not used a pcb layout; the circuit can easily be built onto strip board.

The PIC software

The PIC software does not decode the barcode number (this is done by the PC software), it converts the barcode into a corresponding width. As the wand is moved across

PARTS LIST *for the barcode interface*

Components

R1	10k
R2	330R
C1, C2	33pF
X1	4MHz

PIC pin-out

PIC16C84	Pin #
RA0	17
RB0	6
OSC	15
OSC	16
MCLR	4

Vcc pin 14, ground pin 5

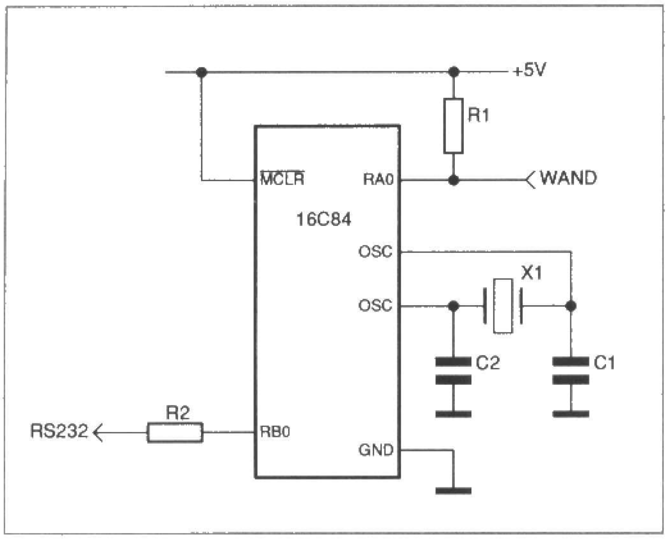


Figure 4: the circuit diagram of the interface

the barcode the background colour produces a return signal to the wand detector and is taken as logic '0', bar as logic '1' (some may view this as inverted logic).

The program waits until the barcode wand detector receives a signal (white) and the start of the quiet zone is assumed. The PIC program times the relative width of the initial guide bars to work out the various barcode widths; the black guide bar is taken as width '1'.

When the scan is finished the PIC sends a 255 (decimal) character indicating end of barcode. This happens when either the barcode scan has entered the opposite quiet zone or if the scan has taken too long (timeout). PIC 16C84 does not have an in-built serial port, so software is used to emulate serial communications via Port B (B0).

Data is received from the PIC at 57600 baud, 8-bit data and no parity. There is no handshaking between the PIC and the PC, as the PIC cannot buffer the barcode data. The received information is a block of numbers ranging from 1 to 4 representing the barcode widths, ending in 255. To help identify whether the width is black or white, the most significant bit is set for black.

The PIC program executes the following steps:

1. Wait for the quite zone (wait for the input to go low).
2. Wait for the first black edge (keep on checking the input until it goes high).
3. Time the width of the first black bar (the guide bar) this will be used as the initial ratio for the black bars.
4. Adjust the timer interval to maximise the range.
5. Output black bar length 1.
6. Time the width of the first white bar. This will be used as the initial ratio for white bars.
7. Output white bar width 1.
8. Time length of next black bar.
9. If the bar is less then 150% of the ratio then output 1.
10. If the bar is greater than or equal to 150% and less than 250% of the ratio then the output is width 2.
11. If the bar is greater than or equal to 250% and less than 350% of the ratio then the output is width 3.
12. If the bar is greater than or equal to 350 % of the ratio then the output is width 4.
13. If the bar is length 1 then add its time to the ratio and divide by 2 to give the new ratio. This then adjusts the ratio to deal with change of scanning speed.
14. If the bar is length 2 then divide it by 2 and add its time to the ratio and divide the result by 2. This then adjusts the ratio to deal with changes of wand scanning speed.
15. Output black bar width.
16. Repeat steps 8 to 15 for the white bar.
17. Repeat steps 8 to 16 until either scan exceeds maximum time or quiet zone reached.
18. Output 255 (decimal) to show end of scan.
19. Goto step 1.

To achieve a divide by 2, the binary RRF instruction (rotate right) is used. These PIC width calculations needs to be done for each barcode scan, as the various segment times will vary according to the speed at which the wand was moved across the barcode. This is unlikely to be the same for every scan. A constant speed across the barcode will considerably improve the reading accuracy.

The complete ASM assembler code is given. Microchip MPASM version 2.01 assembler software was used. Part of the ASM cross reference file is given so that the source program can be checked for typing errors.

The PC Windows program cannot start to decode until the entire scan has finished; the PC program has to store all the information waiting for the 255 characters to be received.

The PIC ASM Program

```
;
; Barcode - PIC16C84
;
; (c) 1998 Roger Thomas
;
; You can use this code for your own personal use.
; Any distribution or commercial use without written
; permission is strictly prohibited.
;
        list    p=16C84,r=HEX
        __config H'3ff1'

OPT     equu    H'1'    ; Option register
RTCC    equ     H'1'    ; Timer
STATUS  equ     H'3'    ; STATUS register

PORTSGequ       H'5'    ; Port with input signal
PORTRSequ       H'6'    ; Port with RS232 output signal

INTCON  equ     H'0B'   ; Interrupt register

C       equ     H'0'    ; Carry flag
Z       equ     H'2'    ; Zero flag
RP0     equ     H'5'
GIE     equ     H'7'

TxChr   equ     H'20'   ; Next character to transmit
PortB   equ     H'21'   ; Storage of Port B
TxCnt   equ     H'22'   ; Loop count for transmit
TxLoop  equ     H'23'   ; Timing loop for transmission
Flags   equ     H'24'   ; General purpose flags
LastRd  equ     H'25'   ; Contents of the last RTCC
CurRd   equ     H'26'   ; Current reading
Work1   equ     H'27'   ; Work space
Work2   equ     H'28'   ; Work space
Work3   equ     H'29'   ; Work space
SizeB   equ     H'2A'   ; Size of black bar
```

```
SizeW   equ     H'2B'   ; Size of white bar

;
; Flags
;
TimOut  equ     0       ; Time out
InitW   equ     1       ; Has white been initialised
InitB   equ     2       ; Has black been initialised

RSOut   equ     0       ; RS232 Out Port B bit 0
PEN     equ     0       ; Pen input Port A bit 0

        goto    main
;
; Main control program
;
main    call    reset           ; Reset PIC
main1   bcf     Flags,InitW     ; Clear initialised white
        bcf     Flags,InitB     ; Clear initialised black
        bsf     STATUS,RP0      ; Swap to alternative bank
        movlw   H'C4'           ; Set / 32 to timer
        movwf   OPT
        bcf     STATUS,RP0      ; Swap to normal bank
main2   movf    LastRd,w        ; Set the time out period
to half the original
        addlw   H'80'
        movwf   LastRd
        call    white           ; Wait for quite zone
        btfss   Flags,TimOut    ; Loop if it got a signal in
the time zone
        goto    main2
main3   call    white           ; Wait for end of quite
zone
        btfsc   Flags,TimOut
        goto    main3
main4   call    black           ; Get length of black bar
        btfsc   Flags,TimOut    ; Abort if time out
        goto    main5
        call    cnvb            ; Convert bar into 1-4
        call    tx              ; Send it
        call    white           ; Get length of white bar
        btfsc   Flags,TimOut    ; Abort if it timed out
        goto    main5
        call    cnvw            ; Convert bar into 1 - 4
        call    tx              ; Transmit white bar
        goto    main4
main5   movlw   H'0ff'          ; Send end of barcode
character
        movwf   TxChr
        call    tx
        goto    main1           ; Wait for next barcode
;
; Changes the time reading for the black bar into
; lengths of 1, 2, 3, 4. Changes the reference to
; deal with changes in scanning speed
;
cnvb    btfsc   Flags,InitB ; Has it already been initialised
        goto    cnvb2
        movlw   H'081'  ; Return black bar width of 1
        movwf   TxChr
        call    calib   ; Modify the timer if required
        bsf  Flags,InitB    ; Set conversion complete
        return
cnvb2   movlw   H'081'      ; Set to return black bar length 1
        movwf   TxChr
        movf    Work1,W  ; Store current width
        movwf   Work3
        bcf     STATUS,C ; Now half the value
        rrf     SizeB,W
        subwf   Work1,W  ; and take it away from the
current reading
        btfss   STATUS,C
        goto    cnvb3
        movwf   Work2    ; Now store it
        movf    SizeB,w  ; Take away current size
        subwf   Work2,f  ; Store the result
        btfss   STATUS,C ; Greater than the size ?
        goto    cnvb3
        movlw   H'082'   ; Set to return black bar length 2
        movwf   TxChr
        bcf     STATUS,C ; Divide current width by 2
        rrf     Work3,f
        movf    SizeB,w  ; Subtract size again
        subwf   Work2,f
        btfss   STATUS,C ; Greater than the size
        goto    cnvb3
        movlw   H'083'   ; Set to return black bar length 3
        movwf - TxChr
        movf    SizeB,W  ;Set width to current
        movwf   Work3
        movf    SizeB,w  ;Subtract size again
        subwf   Work2,W
        btfss   STATUS,C ; Greater than the size
        goto    cnvb3
        movlw   H'084'   ; Set to return black bar length 4
        movwf   TxChr
cnvb3   movf    Work3,w  ; Add new width to old width
        addwf   SizeB,f
        bcf     STATUS,C ; and divide by 2 to give new
width
        rrf     SizeB,f
        return

;
; Changes the time reading for the black bar
; into lengths of 1, 2, 3, 4. Changes the reference
; to deal with changes in scanning speed
;
cnvw    btfsc   Flags,InitW ; Has it already been initialised
        goto    cnvw2
        movf    Work1,W  ; Set the size of the white bar
        movwf   SizeW
        movlw   H'01'    ; Return black bar width of 1
        movwf   TxChr
        bsf     Flags,InitW ; Set conversion complete
        return
cnvw2   movlw   H'01'    ; Set to return white bar length 1
        movwf   TxChr
        movf    Work1,W  ; Store current width
        movwf   Work3
        bcf     STATUS,C ; Now half the value
        rrf     SizeW,W
        subwf   Work1,W  ; and take it away from the
current reading
        btfss   STATUS,C
        goto    cnvw3
        movwf   Work2        ; Now store it
        movf    SizeW,w      ; Take away current size
```

```
        subwf   Work2,f         ; Store the result
        btfss   STATUS,C        ; Greater than the size ?
        goto    cnvw3
        movlw   H'02'   ; Set to return white bar length 2
        movwf   TxChr
        bcf     STATUS,C        ; Divide current width by 2
        rrf     Work3,f
        movf    SizeW,w         ; Subtract size again
        subwf   Work2,f
        btfss   STATUS,C        ; Greater than the size
        goto    cnvw3
        movlw   H'03'   ; Set to return white bar length 3
        movwf   TxChr
        movf    SizeW,W         ; Set width to current
        movwf   Work3
        movf    SizeW,w         ; Subtract size again
        subwf   Work2,W
        btfss   STATUS,C        ; Greater than the size
        goto    cnvw3
        movlw   H'04'   ; Set to return white bar length 4
        movwf   TxChr
cnvw3   movf    Work3,w   ; Add new width to old width
        addwf   SizeW,f
        bcf     STATUS,C        ; and divide by 2 to give
new width
        rrf     SizeW,f
        return

;
; Called when the first bar is scanned to change the
; timer interval to maximize the accuracy of the readings
;
calib   movf    Work1,W         ; Set the size of the black
bar
        movwf   SizeB
        movlw   H'038'          ; Reading too large
        subwf   SizeB,W
        btfss   STATUS,C
        goto    calib1
        bcf     STATUS,C        ; Divide current length by
2
        rrf     SizeB,f
        bsf     STATUS,RP0  ; Swap to alternative bank
        movlw   H'C5'           ; Set timer to / 64
        movwf   OPT
        bcf     STATUS,RP0      ; Swap to normal bank
        return
calib1  movlw   H'018'          ; Reading too small
        btfsc   STATUS,C
        goto    calib2
        bsf     STATUS,RP0      ; Swap to alternative bank
        movlw   H'C3            ; Set / 16 to timer
        movwf   OPT
        bcf     STATUS,RP0      ; Swap to normal bank
        bcf     STATUS,C
        rlf     SizeB,f     ; Multiply current length by 2
        return
calib2  return

;
; Return the white bar length and return the value in Work1
; If it times out set the time out flag
;
white   bcf     Flags,TimOut    ; Clear time out flag
white2  movf    RTCC,w   ; Store current timer reading
        movwf   CurRd
        movf    LastRd,W
        subwf   CurRd,W         ; Subtract last reading
        movwf   Work1           ; and store time difference
        btfsc   STATUS,Z        ; Test for time out
        goto    white3
        btfss   PORTSG,PEN      ; Is it black ?
        goto    white2
        movf    CurRd,W; Change last reading to current
reading
        movwf   LastRd
        return
white3  bsf     Flags,TimOut    ; Set time out flag
        movf    CurRd,W
        movwf   LastRd
        return

;
; Return the black bar length and return the value in Work1
; If it times out set the time out flag
;
black   bcf     Flags,TimOut    ; Clear time out flag
black2  movf    RTCC,w          ; Store current timer
reading
        movwf   CurRd
        movf    LastRd,w        ; Subtract last reading
        subwf   CurRd,w
        movwf   Work1           ; store the time difference
        btfsc   STATUS,Z        ; Test for time out
        goto    black3
        btfsc   PORTSG,PEN      ; Is it black ?
        goto    black2
        movf    CurRd,W
        movwf   LastRd
        return
black3  bsf     Flags,TimOut    ; Set time out flag
        movf    CurRd,W
        movwf   LastRd
        return
;
; Called at start to reset the PIC
; Enables output and disables interrupts
;
reset   bsf     STATUS,RP0      ; Swap to alternative bank
        clrf    PORTRS          ; Enable Port B as output
        movlw   H'C5'           ; Set / 64 to timer
        movwf   OPT
        bcf     STATUS,RP0      ; Swap to normal bank
        bcf     INTCON,GIE      ; Disable all interrupts
        clrf    LastRd
        return

; Transmit a character
;
; TxChr - Character to transmit at 57600 baud (no
handshaking)
;
tx      movf    PORTRS,W        ; Get current port status
        movwf   PortB           ; and store it
        bsf     PortB,RSOut     ; Make sure output is high
        movlw   9               ; Loop 9 times the last
                                  being the stop bit
        movwf   TxCnt
```

```
tx1     movf    PortB,W         ; Get current work status
        movwf   PORTRS          ; Update the port
        bsf     PortB,RSOut     ; Set output to high
        bsf     STATUS,C        ; Make sure that the stop
                                  bit is the correct level
        rrf     TxChr,f         ; Get next bit to send
        btfsc   STATUS,C  ; Set output to low if necessary
        bcf     PortB,RSOut
        nop                     ; Add extra 2 micro
                                  seconds to loop
        nop
        movlw   1               ; Set up delay loop
        movwf   TxLoop
        nop
tx2     decfsz  TxLoop,f        ; Delay complete ?
        goto    tx2
        decfsz  TxCnt,f         ; All bits sent ?
        goto    tx1
        bcf     PortB,RSOut     ; Set output low
        movf    PortB,W
        movwf   PORTRS
        return

        end

MPASM 02,01 Released Cross Reference File

LABEL   TYPE SOURCE FIsLE REFERENCES

C       C 26* 108, 111, 116, 120, 124, 132, 138, 158, 161,
        166, 170, 174, 182, 188, 200, 202, 210, 216, 290,
        292.
CurRd   C 37* 227, 229, 235, 239, 249, 251, 257, 261.
Flags   C 35* 62, 63, 72, 75, 78, 83, 97, 102, 146, 152,
        225, 238, 247, 260.
GIE     C 29* 27.
INTCON  C 24* 274.
InitB   C 50* 63, 97, 102.
InitW   C 49* 62, 146, 152.
LastRd  C 36* 68, 70, 228, 236, 240, 250, 258, 262, 275.
OPT     C 17* 66, 206, 214, 272.
PEN     C 54* 233, 255.
PORTRSC 22* 270, 282, 288, 305.
PORTSGC 21* 233, 255.
PortB   C 32* 283, 284, 287, 289, 293, 303, 304.
RPO     C 28* 64, 67, 204, 207, 212, 215, 269, 273.
RSOut   C 53* 284, 289, 293, 303.
RTCC    C 18* 226, 248.
STATUS  C 19* 64, 67, 108, 111, 116, 120, 124, 132, 138,
        158, 161, 166, 170, 174, 182, 188, 200, 202, 204,
        207, 210, 212, 215, 216, 231, 253, 269, 273, 290,
        292.
SizeB   C 41* 109, 114, 122, 128, 130, 137, 139, 197, 199,
        203, 217.
SizeW   C 42* 149, 159, 164, 172, 178, 180, 187, 189.
TimOut  C 48* 72, 75, 78, 83, 225, 238, 247, 260.
TxChr   C 31* 89, 100, 105, 119, 127, 135, 151, 155, 169,
        177, 185, 291.
TxCnt   C 33* 286, 301.
TxLoop  C 34* 297, 299.
Work1   C 38* 106, 110, 148, 156, 160, 196, 230, 252.
Work2   C 39* 113, 115, 123, 131, 163, 165, 173, 181.
Work3   C 40* 107, 121, 129, 136, 157, 171, 179, 186.
Z       C 27* 231, 253.
__16C84V 13*
black   A 77, 247*
black2  A 248* 256.
black3  A 254, 260*
calib   A 101, 196*
calib1  A 201, 209*
calib2  A 211, 219*
cnvb    A 80, 97*
cnvb2   A 98, 104*
cnvb3   A 112, 117, 125, 133, 136*
cnvw    A 85, 146*
cnvw2   A 147, 154*
cnvw3   A 162, 167, 175, 183, 186*
main    A 56, 61*
main1   A 62* 91.
main2   A 68* 73.
main3   A 74* 76.
main4   A 77* 87.
main5   A 79, 84, 88*
reset   A 61, 269*
tx      A 81, 86, 90, 282*
tx1     A 287* 302.
tx2     A 299* 300.
white   A 71, 74, 82, 225*
white2  A 226* 234.
white3  A 232, 238*

LABEL TYPES
A Address
C Constant
V Variable

Program Memory Words Used: 212
Program Memory Words Free: 812

Errors   : 0
Warnings :  0 reported,  0 suppressed
Messages :  0 reported,  0 suppressed
```

MEMORY USAGE MAP ('X' = Used, '-' = Unused)

```
0000 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
0040 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
0080 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
00C0 : XXXXXXXXXXXXXXXX XXXX------------ ---------------- ----------------
2000 : ---X---- -------- -------- --------
```

All other memory blocks unused.

PC Software

The Windows 95 program receives the information from the PIC via the serial interface. The various barcode widths, as received from the PIC, are displayed and translated into a barcode binary sequence. This sequence should begin with 101 (the guide bar) but the two end guide bars and the middle guide bar are not part of the actual number and need to be removed.

This binary width pattern needs to be converted to a sequence of numbers by the use of the three different tables. Once converted this number needs to be verified and simple checks are performed to make sure that there are 13 digits and the number starts with either 5 or 97.

Once the number has passed these simple checks then it needs to be verified. This is done by removing the last digit (the check digit) and using all the remaining numbers to generate a check digit. This same algorithm was used to produce the original check digit - the algorithm is given below. If a valid barcode is received but is not a UK number then the program displays the country that has been allocated that prefix number.

Example: To calculate the check digit (C) for the EAN-13 number 500246813579C

Starting with the left side of the number sum alternate even numbers
0 + 2 + 6 + 1 + 5 + 9 = 23

Multiply the result by three
23 x 3 = 69

Sum the remaining odd numbers
5 + 0 + 4 + 8 + 3 + 5 = 25

Add both numbers together
69 + 25 = 94

The check digit is the smallest decimal integer number than when added to the previous result produces a number evenly divisible by 10.

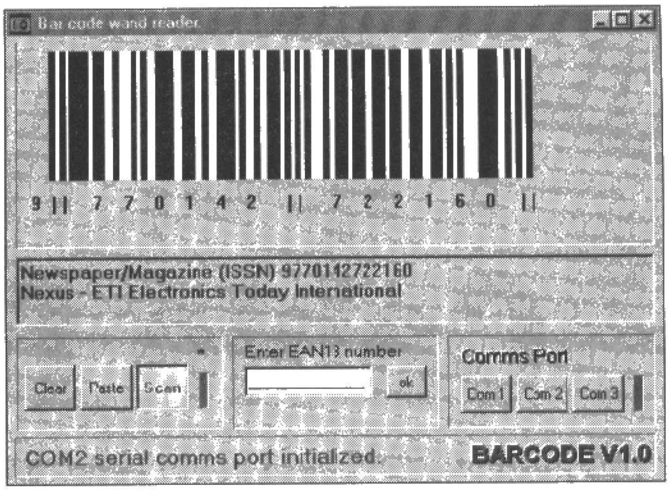
94 - C = 90 therefore C = 4

The complete number = 5002468135794

(This is the same algorithm as used by UPC bar codes).

A simple numeric compare is made between the check digit received and what has just been calculated. If they are the same then this verifies the correct operation of the barcode scan, if they are not then the scanned barcode must be rejected.

After verification, the barcode number is used as an index to search a product database. If the number is found the



associated information is displayed. EAN-13 barcode numbers can also be typed in directly.

The Windows 95 program allows the user to create a data text file that incorporates barcode number and product information that the user is interested in. Typing in barcode numbers and descriptions of 'favourite' products can say a great deal about the user!

For those who do not have a 16C84 programmer I can supply a pin-for-pin compatible programmed PIC. A free demo version of the Windows 95 barcode software to verify the correct operation of the wand and interface is available. This will verify that the PIC software and connection cable is working correctly. The demo software decodes and displays the barcode number, but does not have a database facility or the ability to enter EAN-13 numbers. Please send a 3.5-inch disk and suitable SAE, or just an SAE if enquiring about the PIC availability.

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References

The Article Number Association (UK) Ltd., 11 Kingsway, London WC2B 6AR.

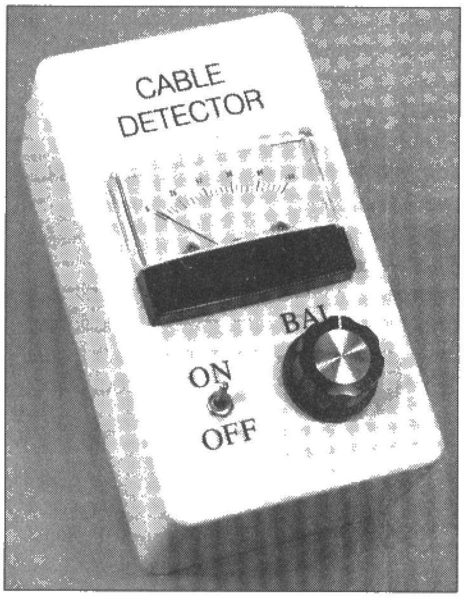
Acknowledgements

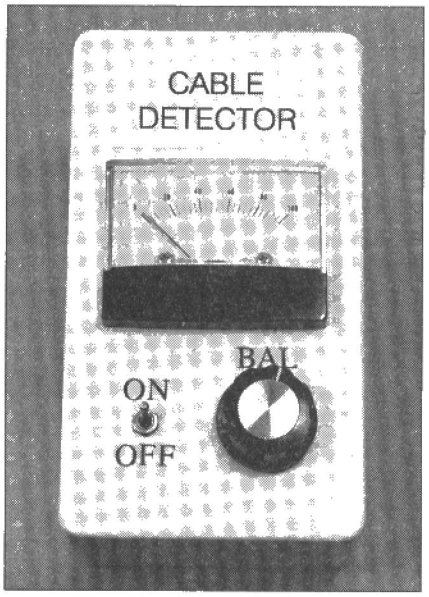
My thanks to Andrew Thomas for help with the PIC programming.
PIC is a registered trademark of Microchip Technology Incorporated, USA.
Windows 95 is a registered trademark of the Microsoft Corporation.

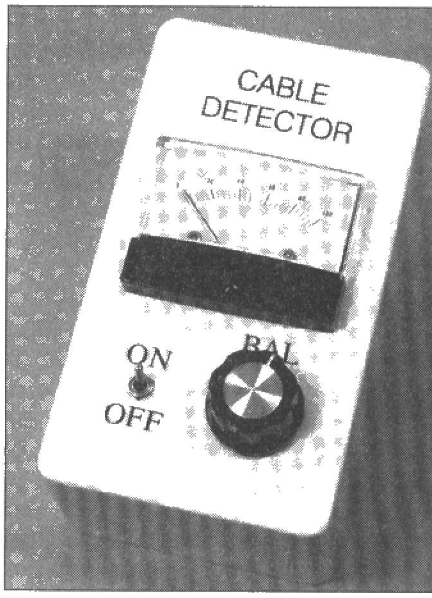
Metal Pipe, Nail and Cable Detector

This portable VLF phase metal detector can locate small objects near the surface of a wall and large objects more deeply embedded

Robert Penfold







DIY is probably more popular now than ever before, and it is certainly possible to save a great deal of money by doing your own home repairs and improvements. It can also provide a great deal of fun for those of a practical disposition. On the other hand, it is not totally hazard-free, and it can be extremely dangerous unless suitable safeguards are observed. The device featured here helps to keep things as safe as possible by helping the DIY enthusiast locate pipes and cables buried in walls. It can also be used to locate small items of metal that are embedded in walls or in woodwork, such as screws and nails. It is really a form of metal detector, which means that it will not find non-metallic items such as plastic pipes.

Some units of this general type are good at finding small pieces of metal close to the search coil, but are virtually "blind" to large chunks of metal unless they are also very close to the detector coil. Conversely, other units are good at finding large items some distance from the search coil but give little response to small pieces of metal even at virtually "point blank" range. This detector has excellent sensitivity to both small and large items, making it equally suitable for locating small nails just below the surface or pipes buried 50 to 100 millimetres into a wall. The unit is completely portable and is powered from a PP3 size battery. When metal is detected there is a clear indication from a moving coil meter, which gives an increased reading for ferrous metals or a reduced reading for non-ferrous metals. Its ability to distinguish between the two types of metal is probably not of any great importance in the current context, but I suppose it could be of help on occasions.

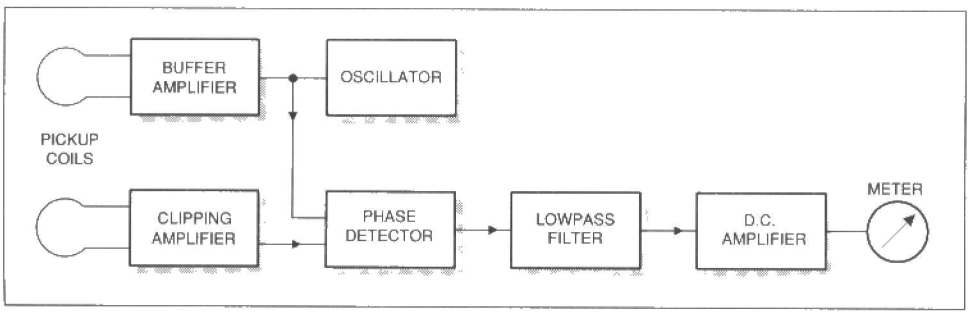


Figure 1: the block diagram of the cable detector

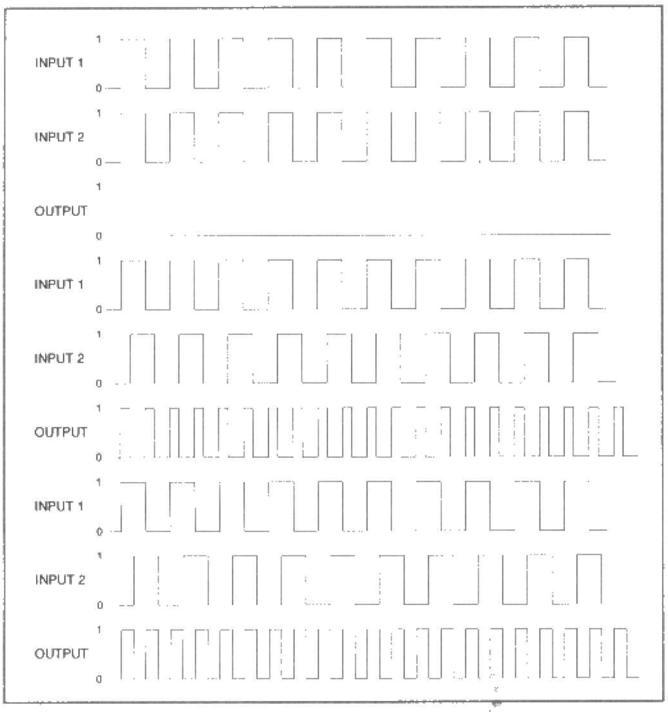


Figure 2: example waveforms for the phase detector

VLF Phase Shift

There are several common methods of metal detection, but virtually all of them rely on a pick-up coil or coils, and the fact that metal near a coil changes the coil's electrical characteristics. This circuit is no exception, and it uses a type of location known as very low frequency (VLF) phase detection. The block diagram of figure 1 helps to explain the way in which this system functions. An oscillator operating at a very low frequency, which in this context means about 20 kHz, drives the primary winding on the pick-up coil via a buffer amplifier. The buffer stage ensures that any metal near the coil does not have a "pulling" effect that could result in distortion to the output waveform of the oscillator. A secondary winding on the pick-up coil feeds a high gain clipping amplifier which produces an output signal that is essentially the same as the direct signal from the oscillator. A phase detector then compares these two signals. With no metal near the search coil there will be only a small phase difference between the direct signal from the oscillator and the signal received via the coil. Any metal near the pick-up coil produces a change in the phase difference, and the direction of the change depends on whether the metal is ferrous or non-ferrous. This phase change must be converted into a change in voltage that can be indicated via a meter.

The phase detector used in this circuit is an ordinary CMOS exclusive OR (XOR) gate. We require a phase comparator that produces increased output voltage if the phase difference between the two input signals increases. An exclusive OR gate performs this task very well, and the three sets of waveforms shown in figure 2 help to explain the way in which the phase detection functions. In the top set of waveforms the two input signals are perfectly in-phase and the output of the comparator is always low. Bear in mind here that the action of an exclusive OR gate is different from that of a standard OR gate. With an ordinary OR gate the output is high if either input is high, or if both inputs are high. The output of an exclusive OR gate is only high if one input or the other is high, but not if they both are. In this example both inputs are low, or both inputs are high, and in either case the output is low.

In the middle set of waveforms the two input signals are 45 degrees out of phase. This introduces two periods per cycle when the inputs are at opposite states, and the output of the gate goes high. The output of the gate is high for 25 percent of the time. In the bottom set of waveforms the phase difference has been increased to 90 degrees. This still gives two periods per cycle when the inputs are at opposite states, but these periods are much longer. The output is now high for 50 percent of the time. On its own the gate does not give quite required action, but it is merely necessary to smooth the output pulses to a DC signal using a lowpass filter. This gives an output potential equal to the average output voltage of the gate, and this voltage is proportional to the phase difference at the inputs of the gate.

Returning to figure 1, the output of the phase detector is fed to a lowpass filter, and an amplifier then boosts the resultant DC output signal. The phase change produced by even a large chunk of metal very close to the pick-up coil is likely to be no more than one or two degrees, and in normal use phase changes of well under one degree must be detected. A substantial amount of amplification is therefore required in order to produce a large enough voltage swing to operate the moving coil meter at the output of the circuit.

The circuit

The full circuit diagram for the Cable Detector project appears in figure 3. IC1 is used in the oscillator stage, which is a conventional 555 astable circuit. The values of R1, R2 and C2 provide an almost squarewave output at a frequency of approximately 20 kHz. With some types of metal locator there is an advantage in using a relatively high frequency, but this does not seem to give a significant improvement in sensitivity

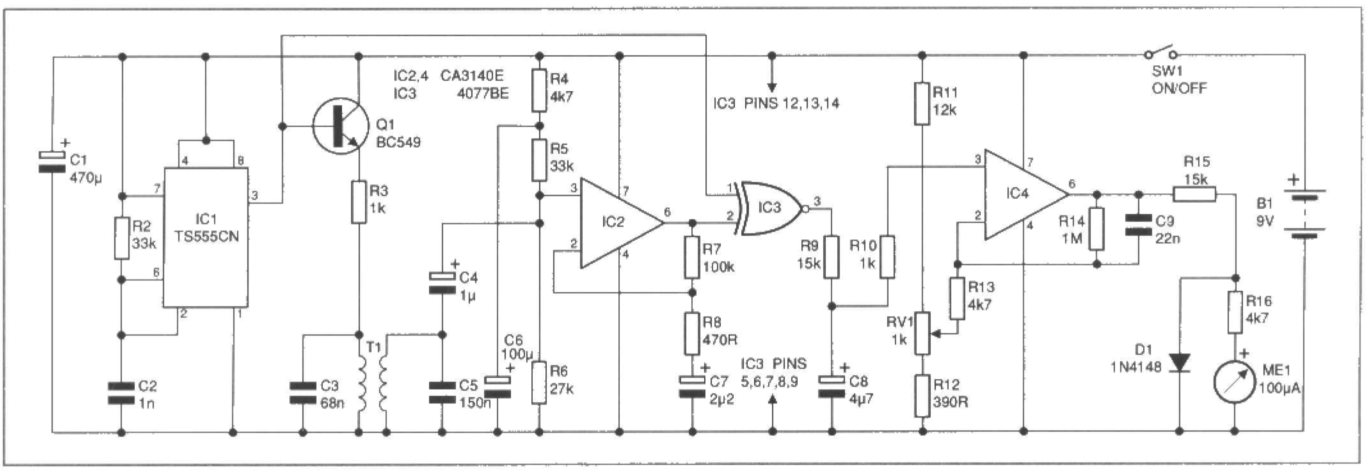


Figure 3: the full circuit diagram for the cable detector

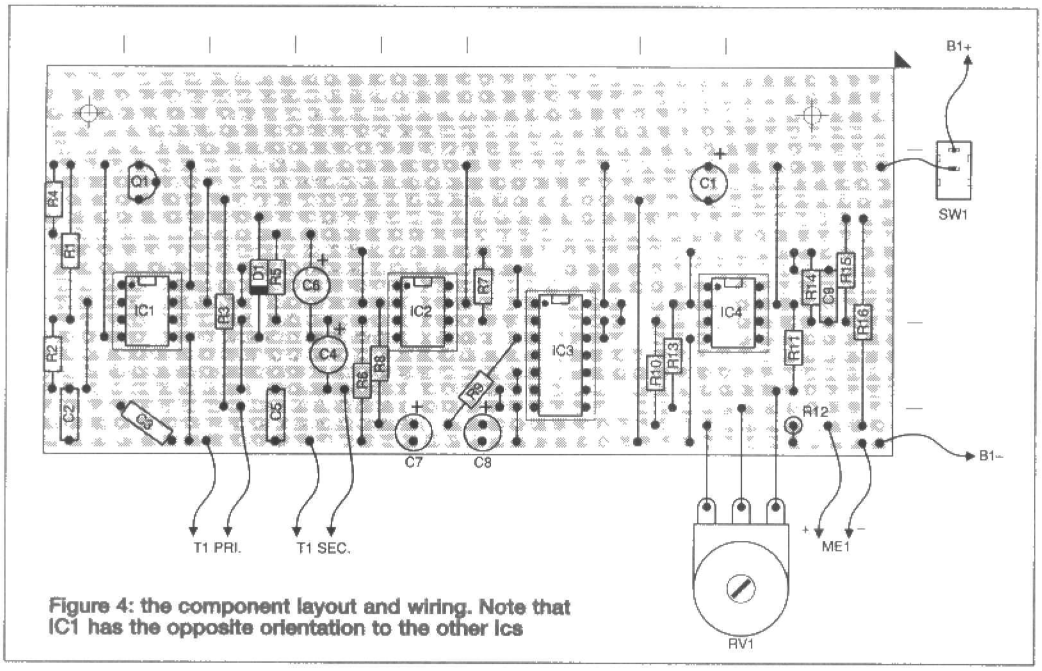
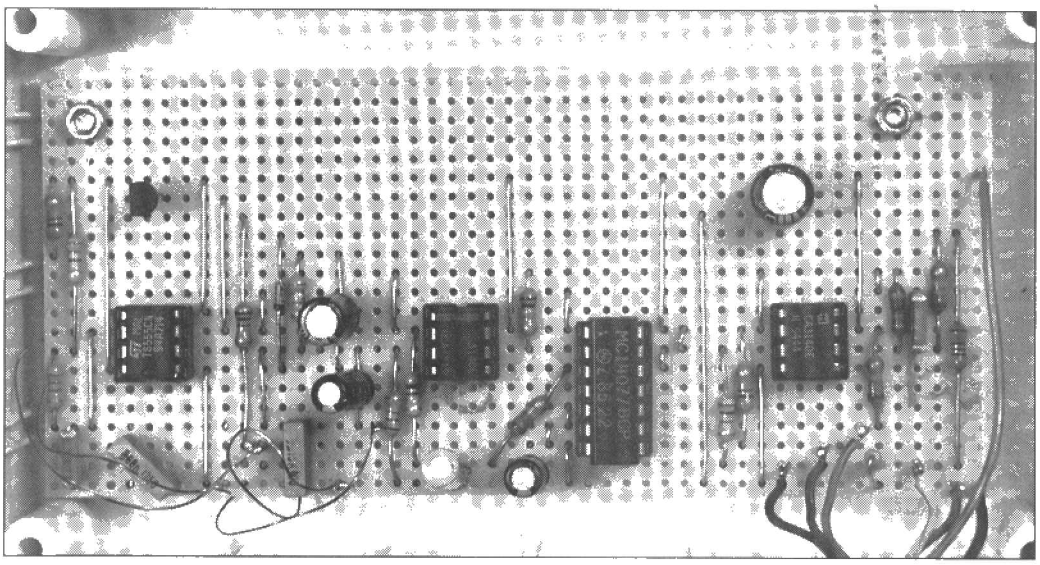


Figure 4: the component layout and wiring. Note that IC1 has the opposite orientation to the other Ics



with a phase shift detector. For a locator that will be used as a "treasure" locator there is a definite advantage in using a low frequency. Using a low frequency usually eliminates ground effect problems. In other words, it removes problems with the detector being activated slightly when the search coil is close to the ground, even if there is no metal in the ground. In the current context this is also an advantage, as the walls of a house can produce much the same problem. Tests on the prototype detector produced no noticeable change in the meter reading with the search coil placed next to walls, people, or other non-metallic objects.

Q1 is used as an emitter follower buffer amplifier at the output of the oscillator, and this drives the primary winding of the search coil (T1) by way of current limiting resistor R3. The primary and secondary windings of the search coil are used in parallel tuned circuits, with C3 and C5 acting as their respective tuning capacitors. C4 couples the output of the secondary winding to a high gain amplifier based on operational amplifier IC2. This stage is a simple non-inverting amplifier having a voltage gain of a little over 200, which is sufficient to ensure that the strong output signal from T1 is heavily clipped. This produces virtually a squarewave signal that is capable of driving one input of the phase detector (IC3). The other input of IC3 is driven direct from the output of IC1. IC3 is a CMOS quad 2-input XNOR gate rather than an XOR type, but it still provides the required response to changes in phase difference. An XNOR gate is effectively just an XOR type having an inverter at its output. The two input signals to IC3 are in anti-phase so that the average output voltage is low under standby conditions, and not in-phase so that a high average output potential is produced. This is important because the DC amplifier at the output of the circuit is designed to deal with a small offset on the output from the lowpass filter.

The latter is a single stage passive circuit (R9 and C8) that feeds into a non-inverting amplifier based on IC4. The closed loop voltage gain of this stage is a little under 200. Under standby conditions the output voltage from the filter will be under one volt, but this is still more than adequate to send IC4's output fully positive. This is avoided by having the negative feedback circuit connect to the wiper of RV1 rather than to the 0-volt supply rail. RV1 is adjusted to offset the DC bias on the input signal and bring the output voltage of IC1 down to around one-volt. ME1 is fed from the output of IC4 via series resistors R15 and R16, which give a full-scale sensitivity of about two volts. Under quiescent conditions the meter therefore reads approximately half full-scale. D1 ensures that there is no more than very minor overloading of the meter if the output of IC4 goes strongly positive. Note that the output amplifier is reliant on IC4 being an operational amplifier that will operate correctly in single supply DC amplifier circuits. Most other operational amplifiers will not work properly in the IC4 position of this circuit.

The current consumption of the circuit is approximately 10 milliamps. An ordinary PP3 size battery is just about adequate to provide this, and it is not necessary to use some form of "high power" battery.

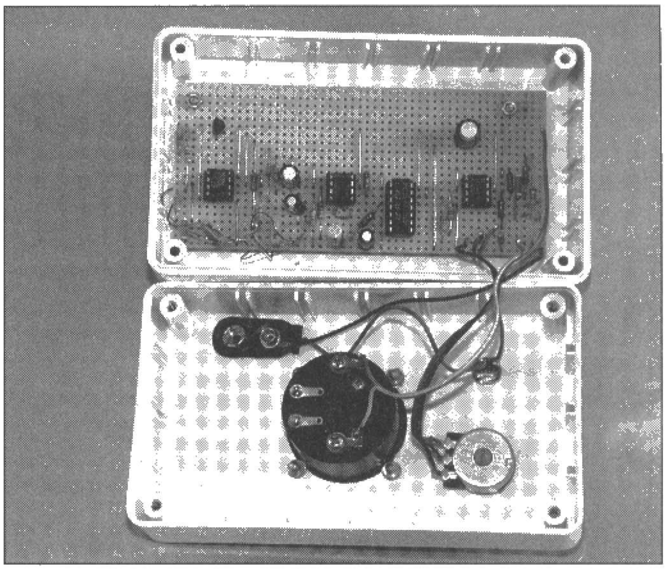
Construction

The component layout and wiring for the cable detector are provided in figure 4, with the underside view of the board show separately in figure 5. Start by cutting out a board of the required size (49 holes by 22 copper strips) using a

hacksaw, and then file any rough edges to a smooth finish. Next drill the two 3.2 millimetre diameter mounting holes and make the breaks in the copper strips. The board is then ready for the components and link-wires to be added. This is largely straightforward, but bear in mind that IC2, IC3 and IC4 are MOS components that require the usual anti-static handling precautions. IC1 is also a MOS device, but it has built-in protection circuits that render any handling precautions unnecessary. It is still advisable to fit this component in a holder, and note that it has the opposite orientation to the other integrated circuits. It is likely that IC1 will be destroyed if it is fitted the wrong way round.

Some of the link-wires are quite long, and it might be worthwhile insulating them with PVC sleeving to make quite sure that there can be no accidental short circuits. The board layout is designed to accept polyester capacitors having 7.5 millimetre (0.3 inch) lead spacing. It could be difficult to fit a different type into this layout, and it is essential to at least use some form of miniature printed circuit mounting capacitor. Fit single-sided solder pins at the points where connections will be made to ME1, RV1, etc.

VLF phase detectors are quite tolerant of metal close to the search coil, and it is not necessary to have the coil well separated from the rest of the unit so that it is clear of the battery, meter, etc. On the other hand, it would be sensible to use a plastic case rather than a metal or plastic and metal type. Practically any medium size case about 135 to 160 millimetres long should be suitable, but the case needs to be fairly deep in order to accommodate the meter. The meter and two controls are mounted on the front panel, with the component panel and search coil fitted on the rear panel. Assuming the meter is a standard 60 by 46 millimetre type, it requires four small mounting holes for its integral mounting bolts. These holes should be about three millimetres in diameter, and are at the corners of a square having sides 32 millimetres long. A large cutout to accommodate the body of the meter is required at the centre of the square, and this has a diameter of 38 millimetres. The easiest way to make this is to use an adjustable hole cutter, or "tank" cutter as they are also known. These are designed to operate at very low speeds, and should really be used in a brace rather than any form of drill. The slower alternative is to use a miniature round file such as an Abrafile, or a fretsaw. With this method it is advisable to cut just inside the required cutout, and then file it out to precisely the required size using a half-round file.



The search coil

The search coil is home-made, and is based on a former about 30 to 35 millimetres in diameter, and about 12 to 15 millimetres long. I used to core of a small reel of 15 millimetre wide Sellotape, which is not particularly expensive if you have to buy it specially and throw away the tape. Two end-cheeks about 50 millimetres in diameter are required, and these are glued to the former to produce a bobbin. These end-cheeks can be made from any strong non-metallic sheet material that is no more than about 3 millimetres thick. Copper laminate board with the copper etched away is suitable, but I used the rear panel of a plastic case removed from a defunct project. I cut them from the panel using an adjustable hole cutter, but a fretsaw or miniature round file again offer an alternative approach. Two pairs of small holes (about one millimetre in diameter) for the leadout wires are needed in one end-cheek. A good quality gap-filling adhesive is required to fix the three parts of the bobbin together. An epoxy type should be suitable, or a glue-gun does the job very well and gives almost instant results.

The primary winding consists of 125 tuns of 34 swg (0.236 millimetre diameter) enamelled copper wire. Thread the wire through one of the holes in the bobbin to leave a leadout wire about 120 millimetres long, and then wind the wire onto the bobbin as tightly as possible. It is not essential to make a neat job of things, but all the turns must run in the same direction, and the turns must be tight so that the finished coil is physically stable. Once the winding has been completed, cut the wire to leave another leadout about 120 millimetres long, and thread it through the second hole in the end-cheek. Mark the bobbin so that you can distinguish between the primary and secondary windings. The process is then repeated for the secondary winding, but using only 50 turns and the second pair of holes. To complete the search coil, wind two or three layers of

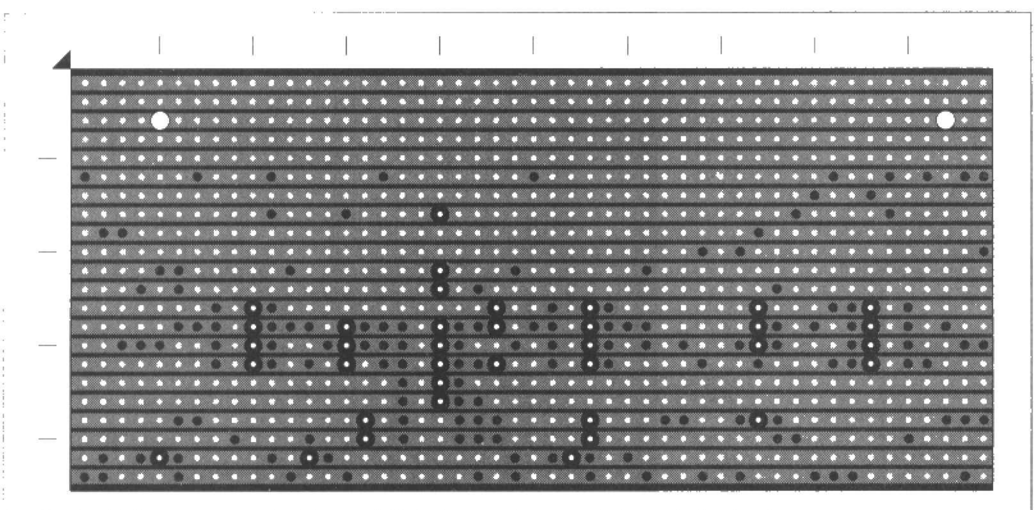
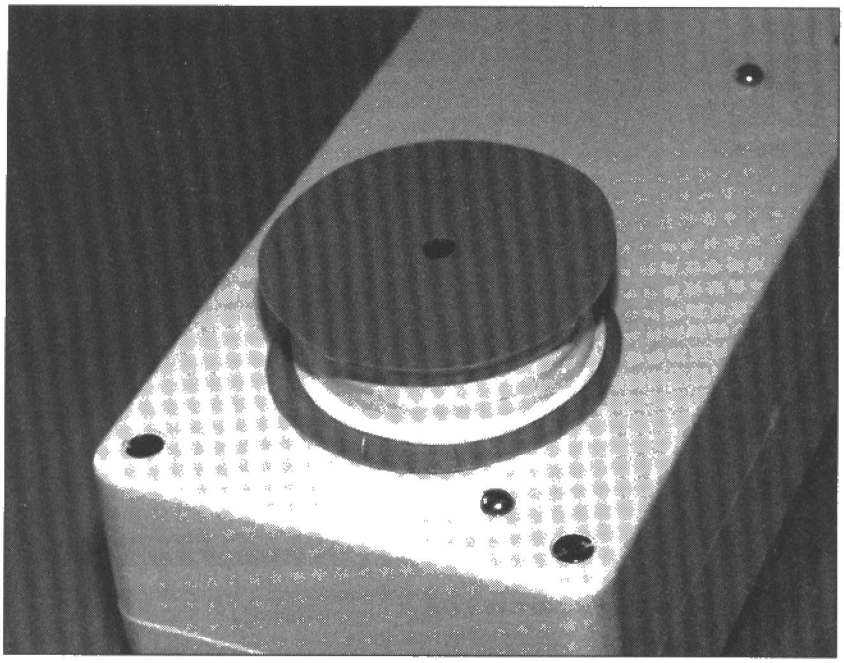


Figure 5. the underside view of the component board


The search coil mounted on the back of the case.

insulation tape tightly around the coil to ensure that the windings stay precisely in position. Figure 6 helps to explain the way in which everything fits together.

The base panel of the case is drilled with holes to match those in the end-cheek of the search coil. The leads are then threaded through these holes and the coil is glued in place on the base panel. Mount the component panel on the other side of the base panel using either 6BA or metric M3 bolts and short spacers.

With the small amount of hard wiring added the unit is ready for a final check and testing. The battery must be properly secured inside the case, as it could produce spurious results if it is allowed to move around. A self-adhesive pad is probably the best way of keeping it in place.

In use

At switch-on the meter will almost certainly read either zero or something close to full-scale, but by carefully adjusting RV1 it should be possible to produce an approximately mid-scale reading. The exact reading under standby conditions is unimportant, but it should be somewhere in the middle of the scale so that the meter can read higher and lower. If you place the meter near something made from iron or steel, such as a pair of pliers, the meter reading should increase. Placing the search coil near some non-ferrous metal, such as an aluminium case or a reel of solder should produce a reduction in the reading from the meter. There may be some "exceptions to the rule", but any non-ferrous items I tested always produced a reduction in the reading from the meter. Due to the high sensitivity of the detector there should be no difficulty in tracing the paths of metal lighting conduits, etc. It should also readily detect nails in doors and walls, etc.

If it is not possible to obtain a mid-scale reading from the meter the most likely explanation is that the phasing of T1 is wrong. Reversing the connections to the secondary winding if T1 will correct this. In use there will inevitably be some drift, and occasional readjustment of RV1 will be required. Eventually more frequent readjustment will be needed, and it will become impossible to obtain a mid-scale reading. It is then time to replace the battery.

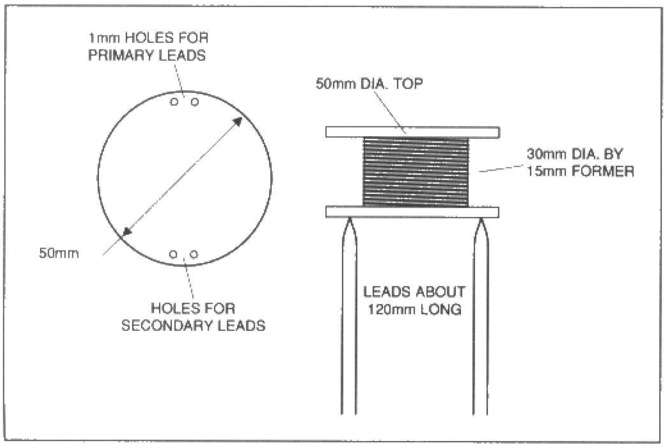


Figure 6: the search coil is wound on a home-made bobbin. The primary has 125 turns, and there are 50 turns on the secondary

PARTS LIST *for the Cable Detector*

Resistors
(5 percent 0.25W carbon film)

R1	3k3
R2, R5	33k
R3, R10	1k
R4, R13, R16	4k7
R6	27k
R7	100k
R8	470R
R9, R15	15k
R11	12k
R12	390R
R14	1M
RV1	1k lin carbon rotary

Capacitors

C1	470u 10V radial elect
C2	1n polyester
C3	68n polyester
C4	1u 50V radial elect
C5	150n polyester
C6	100u 10V radial elect
C7	2u2 50V radial elect
C8	4u7 50V radial elect
C9	22n polyester

Semiconductors

IC1	TS555CN
IC2, IC4	CA3140E
IC3	4077BE
Q1	BC549
D1	1N4148

Miscellaneous

SW1	SPST miniature toggle
B1	9 volt PP3 size
ME1	100uA moving coil panel meter
T1	see text

Plastic case about 142 c 80 c 57 mm. 0.1-inch stripboard 49 holes x 22 strips, 3 x 8-pin dil ic holder, 14-pin dil ic holder, 34 swg (0.236) enamelled copper wire and other parts for T1, control knob, battery connector, wire, solder, etc.

Timing in Electronics

Part 8: Processor Timing

Owen Bishop

Last month's practical project was a circuit for switching a number of lamps or other electrically powered devices according to a timed program. This has applications in home security, as well as in process control generally. In Australia at Christmas-time (and also in USA, I'm told) enthusiasts cover their houses with lighting displays reminiscent of the Blackpool Illuminations. This circuit is ideal for controlling the intricate switching needed to produce a truly mind-bending exhibition.

In the home security application the circuit records the times at which the lamps are switched on and off during a 'learning' period of 24 hours, and repeats the sequence during subsequent 24-hour periods. This month's project is based on a microcontroller instead of a purpose-designed logic circuit. Not only is this circuit much simpler to build but it is more flexible in operation. The circuit is based on the Basic Stamp 2, an expanded version of the original Stamp 1. The Stamps are postage-stamp-sized modules which have a PIC microcontroller incorporated. The components of the Stamp 2 are surface-mount devices mounted on a small rectangle of circuit board, which fits into a standard dil 24-pin socket. They also include a memory chip which allows the Stamps to be programmed in Basic using a PC. It is this feature which makes the Stamps so popular with constructors. When you buy your first Stamp you also need a carrier-board, programming lead, and a floppy disk with the programming files. The Stamps retain their program indefinitely when the power is switched off. They can then be used independently of the PC, but can be reprogrammed at any time later.

Stamp timing

Stamps have built-in timing functions. Part 3 of this series (ETI Vol. 27 Issue 9, of 14th August 1998) showed how to use the PULSIN command for measuring periods of very short duration, such as the length of a photoflash. Stamps are accurate to 1 percent for timing short periods, provided that the measurement is made within the bounds of a single BASIC statement (such as PULSIN). It is possible to measure periods of a few minutes duration by using loops containing one of the other time-dependent commands such as PAUSE. But the execution times of the commands needed to construct these loops are various and we soon begin to lose precision. There is no provision for measuring periods of hours or longer with any degree of precision. A 1 percent error amounts to almost 15 minutes at the end of a 24-hour period and this is not acceptable in most applications.

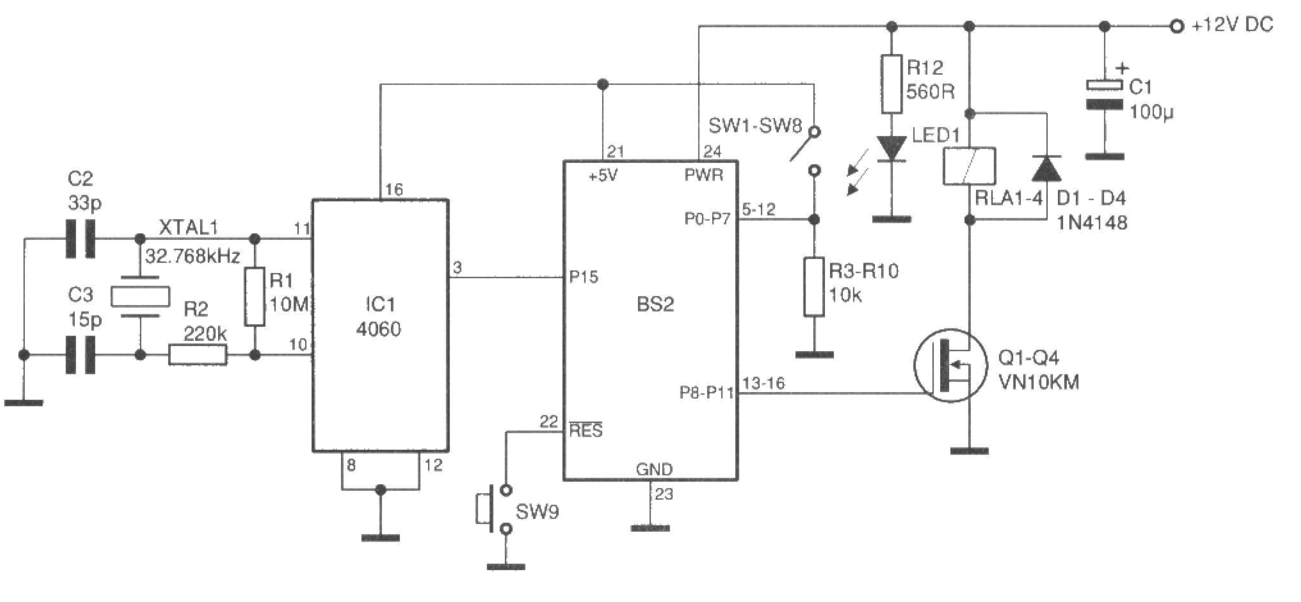


Figure 1: circuit of a learning switch based on a Stamp 2

Application Note #20 of the Programming Manual shows how to use an external crystal oscillator to provide a precise timebase. This uses the CMOS 4060 14-stage counter with its built-in oscillator circuitry. This is the same oscillator that we used for the 1 Hz crystal clock described in Part 2 of this series, except that the Stamp version omits the 4013 flip-flop, so its output runs at 2 Hz instead. **Figure 1** shows a 4060 acting as a precision crystal clock, running at 2 Hz and feeding its output to pin P15 (pin 20 of the Stamp). The figure also shows eight input switches (only one drawn) and four transistor-driven relays (only one drawn) and a reset button. The logic circuits of last month's project are no longer needed, their role being taken over by software. This is the software solution to the problem.

Programming

The usual procedure is to program the Stamp while it is in its socket on the carrier board, using the supplied programming lead. Power is fed to the board from a power pack or battery. The input voltage must be in the range 5 V to 15 V. For this project the chosen supply voltage is 12 V, as used last month. On the carrier board the supply goes to pin 24 (PWR) of the Stamp, which contains a regulator to produce a 5 V supply for the processor and for driving a limited amount of external circuitry.

Normally the Stamp is programmed on the carrier board, and then transferred to its socket on the project board. It is returned to the carrier board if the program subsequently needs to be modified. In this project we need to modify the stored data fairly frequently. This could mean repeatedly transferring the Stamp from the project to carrier board and back again, with the risk of bent pins and other damage. To avoid the hazards and awkwardness of this, the project board has a socket, which accepts the programming lead. The Stamp can be re-programmed and tested without removing it from the project.

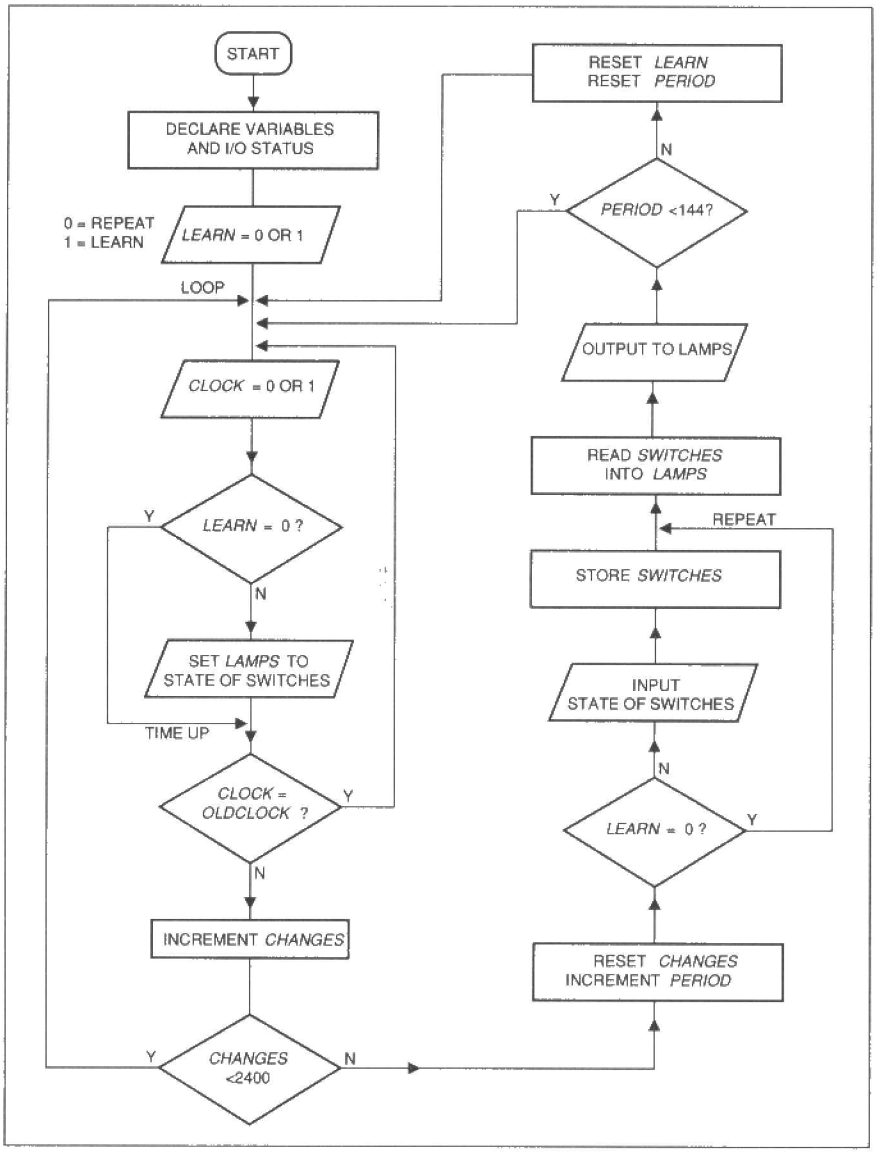


Figure 2: the flow-chart of the learning program

Learning program

The program is based on the following configuration of inputs and outputs:

I/O pin	Stamp pin	I or O	Function
P0	5	I	Setting switch SW1
P1	6	I	Setting switch SW2
P2	7	I	Setting switch SW3
P3	8	I	Setting switch SW4
P4	9	I	Learn/repeat switch SW5
P5 - P7	10-12	I	Spare input switches
P8	13	O	Q1/RLA1, lamp 1
P9	14	O	Q2/RLA2, lamp 2
P10	15	O	Q3/RLA3, lamp 3
P11	16	O	Q4/RLA4, lamp 4
P12-P14	17-19	I/O	Spare input/output pins
P15	20	I	Clock input from IC1

The table shows that there are four setting switches, as in the hardware solution described last month. There are also four relays for switching lamps or other electrically powered devices of suitable rating. There are also spare inputs and outputs that can be used to control additional devices or provide other refinements to the operation of the project.

The program uses seven variables:

clock	The present state of the clock input (0 or 1).
oldclock	The state of the clock input at the previous sampling (0 or 1).
changes	The number of times the clock input has changed from 0 to 1 or from 1 to 0. There are four changes per second or 240 per minute. Changes is reset every time it reaches 240, 1200 (5 minutes) or 2400 (10 minutes).
Period	The number of periods of 1, 5 or 10 minutes duration. Period is reset every 24 hours.
learn	Indicates the mode, 1 = learning, 0 = repeating.
switches	A byte to indicate the state of up to 8 setting switches (0 = open, 1 = closed).
lamps	A byte to indicate the intended state of up to 8 lamps or other devices (0 = off, 1 = on).

Here is the program, which begins by declaring the variables (see the flowchart in **figure 2**):

```
clock var bit
oldclock var bit
changes var word
period var word
learn var bit
switches var byte
lamps var byte
DIRS = %0111111100000000
learn = IN4
loop:
clock = IN15
if learn = 0 then timeup
lamps = INA
OUTC = lamps
timeup:
if clock = oldclock then loop
changes = changes + 1
if changes < 2400 then loop
changes = 0
period = period + 1
if learn = 0 then repeat
switches = INA
write period, switches
repeat:
read period, lamps
OUTC, lamps
if period < 144 then loop
learn = 0
period = 0
goto loop
```

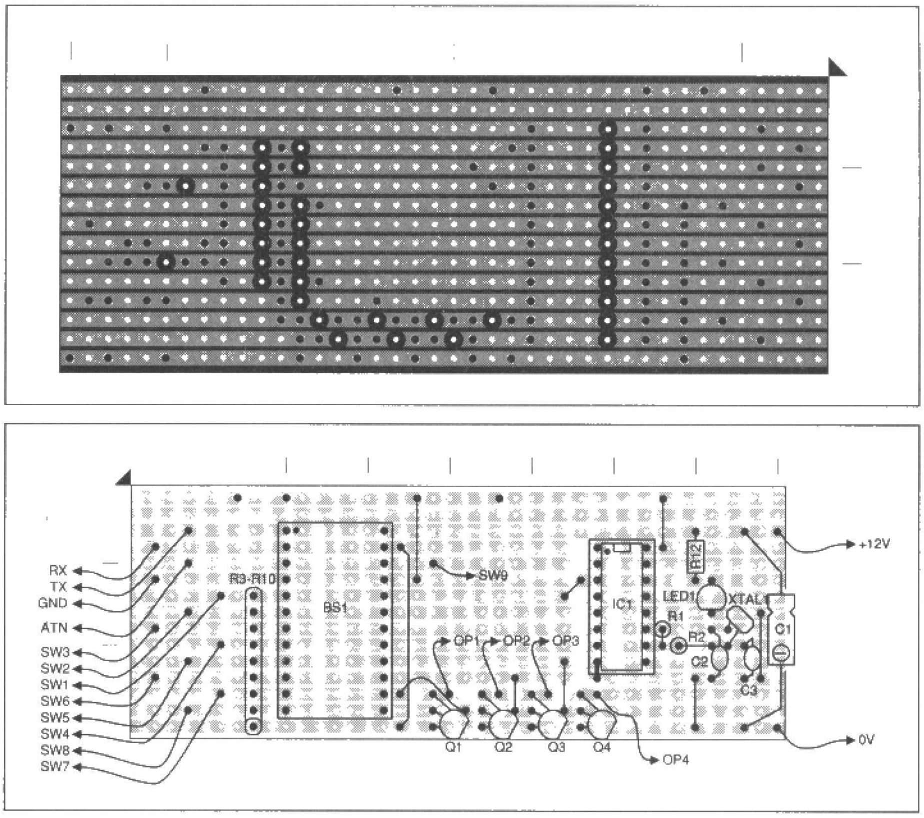
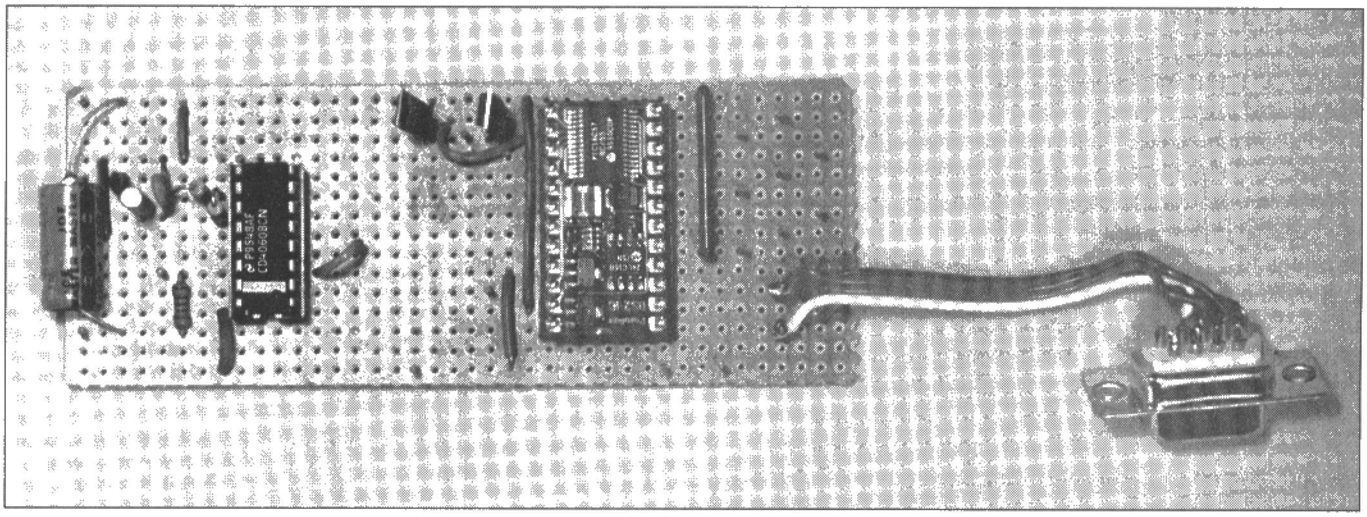


Figure 3: the component layout. This board replaces Boards 1 and 2 of last month's circuit. (Please note that C3 should go to 0V, not to pin 9 as in the photograph.)

During testing, it is better if line 14 is 'if changes [left arrow] 8 then loop'. This gives two-second periods and, if a line 'debug bell' is inserted after 'period = period +1' a beep is heard every time the period is incremented. This gives one beep per two seconds and is useful for checking that the clock is operating at the correct rate. Later, change the line to 'if changes <240' to give one-minute periods. This makes it easy to check the operation of the program quickly. One advantage of the software solution is that it is easy to arrange for periods of convenient lengths, such as 5 min or 10 min, instead of the awkward 11.25 minutes forced on us by the constraints of the logic of the hardware solution.

Assuming that the program is to repeat after 24 hours, the number of periods in line 17 needs to be set according to period length. For 1-min periods, this should read 'if period < 1440 then action'. For 5 minutes the number is 288 and for 10 minutes it is 144. If you are working with a 5 min or 10 min it is also possible to operate the circuit on a 7-day basis. There are 1008 periods of 10 minutes in 7 days. It is possible to record a program showing daily dissimilarity, including markedly different patterns of activity at the weekends. This is something that the original hardware version could not do.

Note that the program automatically switches to repeat mode after 24 hours in learning mode, irrespective of the state of the learn/repeat switch. But the program encounters the line 'learn = IN4' when being re-run from the beginning. So, if you reset the processor by pressing S9 or you switch off the power, it will revert to learning mode the next time it is run. To prevent this from over-writing the stored sequence, it is essential to place S5 in repeat position before resetting or restoring power.



Programming by computer

The learning mode has the advantage that the device records your normal use of the lamps during a 24-hour period. If you prefer to work out the switching pattern in advance, use the PC to program the Stamp directly. In this case there is no learning mode. The program makes use of the Stamp's DATA statement, which should contain 144 or 288 values for 'lamps', depending on the length of the period. A bit in the data values represents each lamp. So the values may range from 0, for all lamps off, to 15 for all four lamps on. Here is the program:

```
clock var bit
oldclock var bit
changes var word
period var word
lamps var byte
DIRS = %0111111100000000
period = -1
table DATA 1,2,2,0,3,13,9,4, ...as required
loop:
clock  = IN15
if clock = oldclock then loop
oldclock = clock
changes = changes + 1
if changes < 2400 then loop
changes = 0
period = period +1
if period < 144 then action
period = 0
action:
READ period, lamps
OUTC lamps
goto loop
```

By default, the program begins with period 0 at whatever time the power is switched on or the reset button is pressed. If you want it to begin at some other stage amend the first 'period =0' statement to some other value. For example, if you are starting off the program at 1600 hrs and your sequencing is based on a 1000-hr start, you need to begin 6 hours into the sequence. At 6 periods per hour the statement should be 'period = 36'. The sequence will run through until 1000 hrs the next day, then repeat normally.

By editing the DATA statement and saving each version of the program, it is simple to produce a set of programs, each with a different switching sequence for different occasions.

Construction

The circuit is built on a piece of stripboard of the same size as Board 1 in last month's project. This board (**figure 3**) replaces both Board 1 and Board 2. The project also needs Board 3, the one, which carries the relays. For details of that board, the enclosure, the panel layout, and the mains wiring, see last month's article. The power supply comes from a 12 V DC unregulated mains adapter, and we use the Stamp's own 5 V regulator.

Before beginning construction, decide on which program or programs you intend to use. If you are going to use only the 'learning' program, you can program the Stamp on its carrier board and will not need the four programming connections shown at the top left of the board. Neither will you need the 9-way socket. If you intend to use only the second program, you do not need the learn/repeat switch SW4. You can program on the carrier board but, as explained above, it is better to program on the project board and you will need the 9-way socket and its connections (see **figure 4**). This also makes it easier to test the wiring and use DEBUG to check for correct operation. Note the connection between channels 6 and 7 of the socket.

Since the clock ic requires the 5 V supply from the Stamp, it is best to complete the circuit-board layout and inspect it visually for faults before inserting IC1 and the Stamp. To simplify the wiring and to save space, a resistor array is used for R3 to R10. The array has 9 pins, the common one being indicated by a bar printed at one end. This pin goes to the 0V rail. The setting switches are wired between the pins SW1 to SW8, and one of the terminal pins on the +5 V rail. The program is more easily tested if connections to the relays are not made at this stage. Temporarily connect an LED in series with a 560-ohm resistor between each of pins OP1 to OP4 and the 12 V rail.

Apply the 12 V supply, then check for 5 V at pin 21 of the Stamp and pin 16 of IC1. Check that the output at IC1, pin 3 rises and falls twice a second. Load the Stamp with the program (if not already loaded) and check its operation.

Refinements

There are several ways in which the spare inputs and outputs may be used with additional programming. An extra input switch can be used to select between two other modes of operation, real-time and stepping. In real-time mode the circuits works as before, learning the sequence over the 24 hours. Alternatively, in stepping mode the program is stepped on manually by pressing a push-button (another additional input). Settings are recorded at each step. One of the outputs could be used with FREQOUT to drive a loudspeaker, producing a beep at the end of each period.

Real-time clock

A real-time clock in a computer system tells the computer what time of day it is and often the date, month and year as well. If a computer system is going to interact with the real world, instead of just going about its business in its own sweet way, it needs to know the time. Computer systems have plenty to do and it is often convenient to have a chip in the system specially dedicated to time-keeping. In the project described above, the combination of the oscillator (IC1) and the program in the Stamp produces a real-time clock that tells the Stamp when to switch the lamps on or off.

Rather more complicated chips are made to act as general-purpose real-time clocks in microprocessor systems. We will look at one example, the HD164818, which is fairly typical of this kind of device. It has a built-in circuitry for a crystal oscillator, needing the same external crystal, resistors and capacitors as the 4060. It works with a 32.768 kHz crystal and can also work with crystals of 32 times and 128 times that frequency. Instead of having an address bus and a data bus, like the 2114 RAM we used last month, this ic has a multiplexed bus. This functions both for

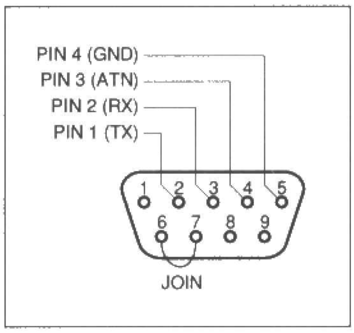


Figure 4: connections to the 9-way socket, as seen from the rear of the socket (solder-cup side)

addressing registers in its memory and for inputting and outputting data. The ic uses time multiplexing in which the bus first acts as an address bus, to identify the register that is to be accessed. Then it becomes a data bus and data is either written into the registers or read from them.

The RAM in the HD164818 has 64 bytes, the first 10 of these being concerned with storing time data. These comprise: seconds, alarm seconds, minutes, alarm minutes, hours, alarm hours, day of week, date of month, month and year. To set the clock, the registers are loaded with the present time: year, month, date, day, hour, minute and second. From then on, with the oscillator running it keeps track of the time, allowing for months of different lengths and for leap years. We have a complete calendar function. In addition it enters an alarm condition (an interrupt) if the seconds, minutes or hours are equal to the values stored in the corresponding alarm registers. This gives the alarm interrupt at the same time each day. Alternatively it can be made to produce an interrupt once every hour, once every minute or once every second. We will discuss how interrupts operate shortly.

A topical point is that the year is stored as a value from 0 to 99. So the clock does not distinguish between the year 1927 and the year 2027, or between any other years of the same number in different centuries. If knowing the year is essential to the operation of the equipment in which this clock is used, the main processor must be programmed to look after this. Otherwise, Y2K strikes again!

The next four registers in the clock's ram consist mainly of 'flags' set to select modes of operation. For example, you can chose to run it as a 12-hour clock or a 24-hour clock, or to enable or disable the interrupt routines. The remaining 50 bytes of memory are available as general-purpose ram.

Interrupts

One way of keeping the processor up-to-date with the time is to get it to read the relevant registers in the real time clock at frequent intervals. It may read the hours register and, when it reads 11 display a message 'Time for coffee break'. Or it may read the month and when it detects that the month has just changed it will start preparing monthly statements for all the customers. Making the processor interrogate the real time clock is known as polling. It polls the register repeatedly until a given condition is met, and then takes appropriate action.

But processors are busy devices and it could happen that it is working on some rather lengthy task (lengthy? well, perhaps something that takes a millisecond or two), when the key condition occurs. It would miss out. Or it may not be able to spare the time to repeatedly poll at the registers that need scanning. A more reliable policy is to get the clock to butt in on the processor's operations in a way that can not be overlooked. This is known as an interrupt. One of the pins of the HD146818 places a low logic level on the interrupt line of the control bus. This is connected to the interrupt input of the processor.

When the processor receives an interrupt it knows that something needs to be done, but it does not know what is to be done. It saves details of the activity in which it was engaged before the interrupt and then jumps to special routines for handling interrupts. One way of finding out what to do next is to poll the registers in the clock, and in any other peripherals of the system which might be interrupting (such as a keyboard). Data read from these will tell the processor what is required of it. It then knows if the keyboard has some key-presses ready to be registered, or if the floppy drive is waiting for some data to store, or if the real-time clock is saying that it is time to update the time display. Interrupts can be given priority ratings so that, if two or more occur at the same time, they are dealt with in a suitable order. If there are many potentially interrupting devices in the system it could take too long to poll them all. In such systems it is more efficient to use vectored interrupts. But since the HD146818 does not respond to these, I had better heed the interrupt from the Editor who is noting that there really is nothing more to be said about real-time clocks and that this series must now be concluded.

PARTS LIST *for the Learning Switch*

Resistors

(5 percent metal film, 0.25 W)

R1	10M (can be carbon)
R2	220k
R3-R10	dil array of 8 commoned resistors, 10k
R11	560 ohm

Capacitors

C1	100 uF axial electrolytic
C2	33 pF metallised ceramic plate
C3	15 pF metallised ceramic plate

Semiconductors

D1-D4	1N4148 silicon diode
IC1	CMOS 4060 14-stage binary ripple counter (with internal oscillator)
BS2	Basic Stamp 2
LED1	5-mm light-emitting diode (in chrome bezel)
Q1-Q4	VN10KM n-channel mosfet

Miscellaneous

XTAL1	32.768 kHz digital watch crystal
RLA1-RLA4	Omron G6B1114P, single-pole, normally-open, 12V coil (Electrovalue)
SW1-SW4	SPST rocker switch, panel-mounting, snap-in
SW9	Push-to-make push-button, panel-mounting

Standard ABS box, 190 mm (110 mm (60 mm (Electrovalue, 508-942), stripboard (two boards to fit enclosure), 1 mm terminal pins (26 off), 2-way pcb mounting terminal blocks (301 series or similar, 5 off), 12-way power terminal block, bolts and nuts to secure block, 16-pin ic socket, 24-pin ic socket, 13A mains plug, 13A mains sockets (4 off), 2-core or 3-core 3A mains cable. D-series solder-type 9-way socket.

BASIC Stamp 2 is available in UK from Milford Instruments, Milford House, 120 South Street, South Milford, Leeds LS25 5AQ. Tel 01977 683665. Fax 01977-681465. In Australia and New Zealand, contact your nearest Dick Smith store. Manufacturer's website (information, programs, and discussion list): http//www.parallaxinc.com . Prices may vary.

Please say that you saw the Basic Stamp in the pages of ETI when contacting your suppliers for components.

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Switch Volt PSU	E/0199/4	£5.09
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Programmable Logic Simulator Board	E/1398/2	£5.09
Regulated Battery PSU	E/1398/3	£5.09
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ETI ELECTRONICS TODAY INTERNATIONAL

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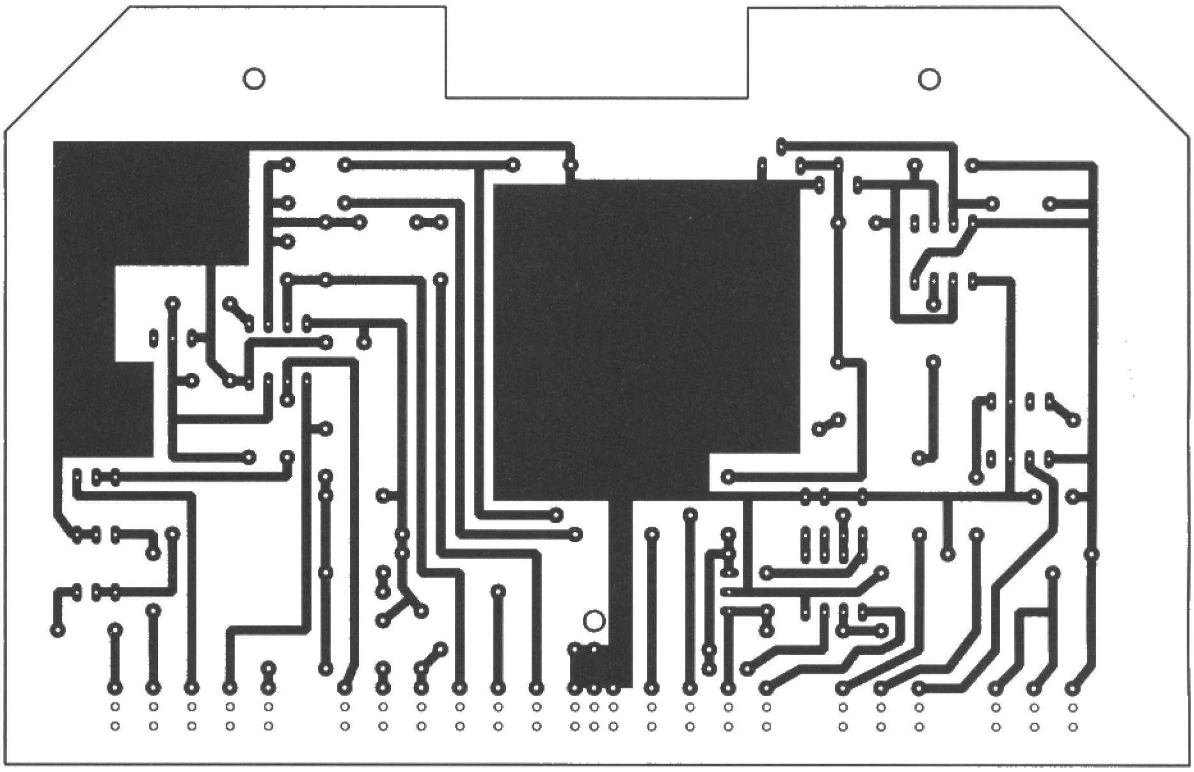

Stress and Skin Temperature Meter

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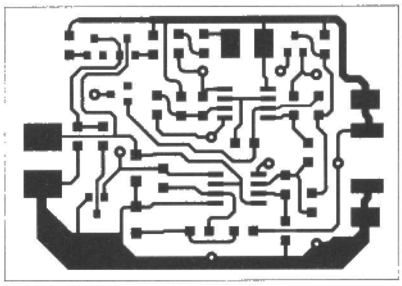
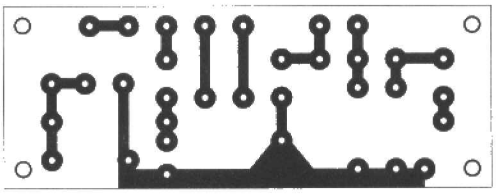
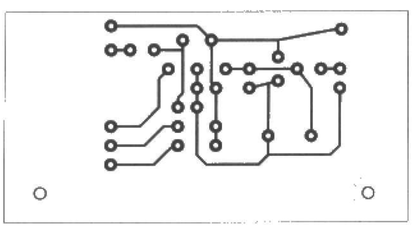


ACTUAL SIZE

'Short Cut' Continuity Tester



RF Probe



Switch Volt Bench PSU

PRACTICALLY SPEAKING

By Terry Balbirnie

Over the last two months of Practically Speaking we have been looking at the magnetic reed switch. This month we shall continue by examining the encapsulated variety and also the reed relay.

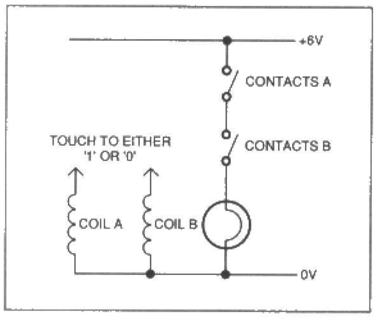


Figure 1: an AND gate

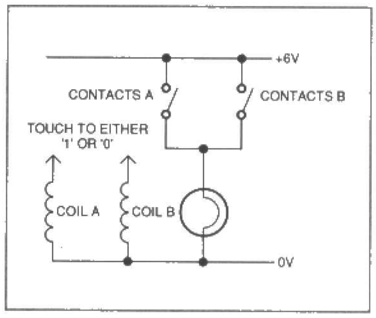


Figure 2: an OR gate

Easily damaged

The glass envelope of the unprotected reed switch is very vulnerable to damage if it is knocked or dropped. More significantly, if the wire ends are bent too close to the body, the glass will crack. In either case the switch will be made useless, so it must be stored handled with due care.

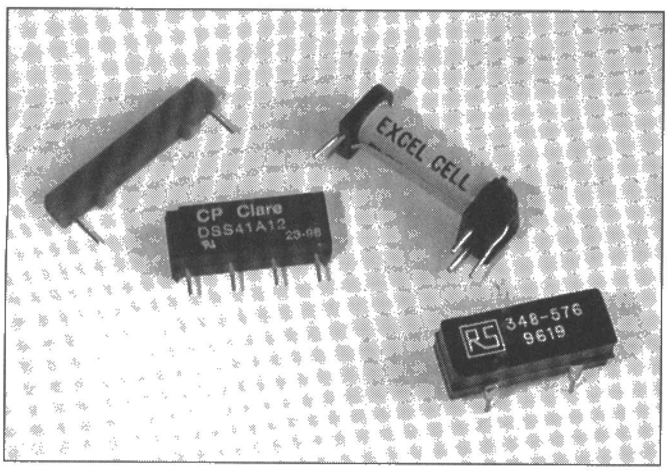
An encapsulated reed switch is more robust because of the protection afforded by the plastic case. Since the wire ends are brought out to pins on the body, they can be plugged into prototype boards. Although more expensive, the encapsulated type would be a better choice for experiments, especially in a school or laboratory environment.

Reed relays

A reed relay consists of an encapsulated reed switch with a coil of insulated copper wire wrapped onto its body. Passing a current through the coil will generate a magnetic field and cause the contacts to operate. The number of turns is usually very high - often several thousand. Suppose the sensitivity of the switch is 20AT (this term was explained last month). It can be seen that if the coil had 2000 turns, it would operate when 10mA flowed through it. Since the wire is extremely thin, it will have a high resistance - say, 1000 ohms. If the ends of the coil were connected to the terminals of a battery, Ohm's Law shows what voltage is needed to operate it:

$V = I \times R; = 0.01 \times 1000 = 10V$

The operating voltage for a given reed relay may be adjusted by the manufacturer by using the appropriate number of turns. In practice, this is usually a nominal 5V or 12V.



Left to right: encapsulated reed switch; single in line (sil) reed relay; stand-type reed relay; reed relay in dual in line (dil) package

Compared with an ordinary relay, a reed relay operates more quickly (typically 1ms compared with about 4ms for a comparable miniature relay of the standard pattern). The reed relay also has a longer life (about 100 million operations at full load compared with some 100,000 for a standard one). However, it has a rather limited voltage/current switching capability. This is likely to be around 500mA at a maximum of 100 volts or so. Exceeding the current, even by a small margin, can cause the contacts to stick together.

Reed relays may be bought in various configurations with single-pole or changeover contacts. Some are built in a 14-pin dil type case so that they may be integrated with ics on the PCB and will also fit a stripboard layout. They are also available in a sil (single in line) outline which have a very narrow profile. These are useful when space is restricted. Some reed relays have a built-in diode connected in parallel with the coil so that an external one is no longer required. However, when using these it is essential to connect the external circuit to the coil in the correct sense. If it was the wrong way round, the diode would be left in a forward-biased state. The current would bypass the coil so it would not work and the diode could be damaged.

Open gate

For demonstration purposes, you can use reed relays to show the principle of 2-input logic gates in a very easy-to-understand way. Use two 5V reed relays in conjunction with a 6V battery and a 6V bulb of either 40mA or 60mA rating. Regard +6V as "logic 1" and the 0V line as "logic 0" as far as inputs are concerned. For the output, regard the bulb being on as a "logic 1" output and off for "logic 0". One pair of coil wires is permanently connected to 0V. The others may be touched on to the 0V (or just left unconnected) or positive rail to give a logic 0 or logic 1 input respectively. The lamp will light or not and the truth table of the gate checked through. In **figure 1**, you need to operate both coils to activate the bulb because the contacts are connected in series. This is equivalent to an AND gate. In **figure 2**, operating either coil will cause the lamp to come on. This is because the contacts are connected in parallel. This is equivalent to an OR gate.

Round the Corner

Good listeners needed

The skills shortage is still with us. Mr. Peter Mandelson and the DTI have launched a new poster campaign to encourage young people, particularly women, to take up science and technology careers. The posters are colourful, detailed and show energetic young women commanding men and machines, having a lively social life and making a respectable living. This life is certainly the least we should offer our scientists, engineers and technicians.

The DTI reports that many 14-16 year old girls are "alienated by what they see as the impersonal and value-free content of science". If that doesn't scare you, it should. Why is science assumed to be more value-free than any other career? Why are other options seen as more personal? Personal experience can be either misunderstood or understood, and the resulting knowledge can be either rubbish or fact. It's usually a messy mix of the two, but anyone who has watched a technician try to assemble a flat-pack desk without reading the instructions first knows that facts are ultimately intractable, regardless of gender and training, whatever spin you put on them. I believe the results are now in the Tate Galley.

The question of why people go into technical careers has not, I believe, been fully addressed. The most concentrated rush of women into IT I recall was in the late 1970s when a sudden need for computer operators pushed salaries up, and good, free training was given.

But most of the women I knew who went into that career fought their way out again eventually. Despite the money and the intellectual challenge, they never became reconciled to spending long hours staring at a machine.

If you work in electronics or IT, you must spend long hours staring at the machine. That (unless you go into management) is the job. Doctors must care about getting people well; parents must care about getting children raised, engineers and technicians must care about getting the machine to work. Researchers say that, above all, women want to communicate. Well, this is a communications issue.

We need engineering managers, but more importantly we need engineering engineers. A capable engineer must want to do the job. He or she must want to stare into the machine, and want desperately to analyse, with a great deal of patience and practice (and gradually developing intuition), what the machine is doing when it stares right back.

It's a communications issue. It's a relationship. Check it out and make sure it's the real thing. If you are still on speaking terms with your machines after 20 or 30 years, you'll be a genuinely useful member of society, and, what is more, you'll be an engineer, my daughter (or son).

Next Month

We join forces with *Everyday Practical Electronics* – see the announcement elsewhere in this issue. Watch out for the joint logos on the front cover of the next issue – published 5th February 1999. Terry Balbirnie has an Auto Cupboard Light . . . Tony Hart keeps tabs of time on video recordings with a Time and Date Generator . . . Bill Mooney makes the workbench fume free with his SMT Smoke Absorber . . . and much more

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